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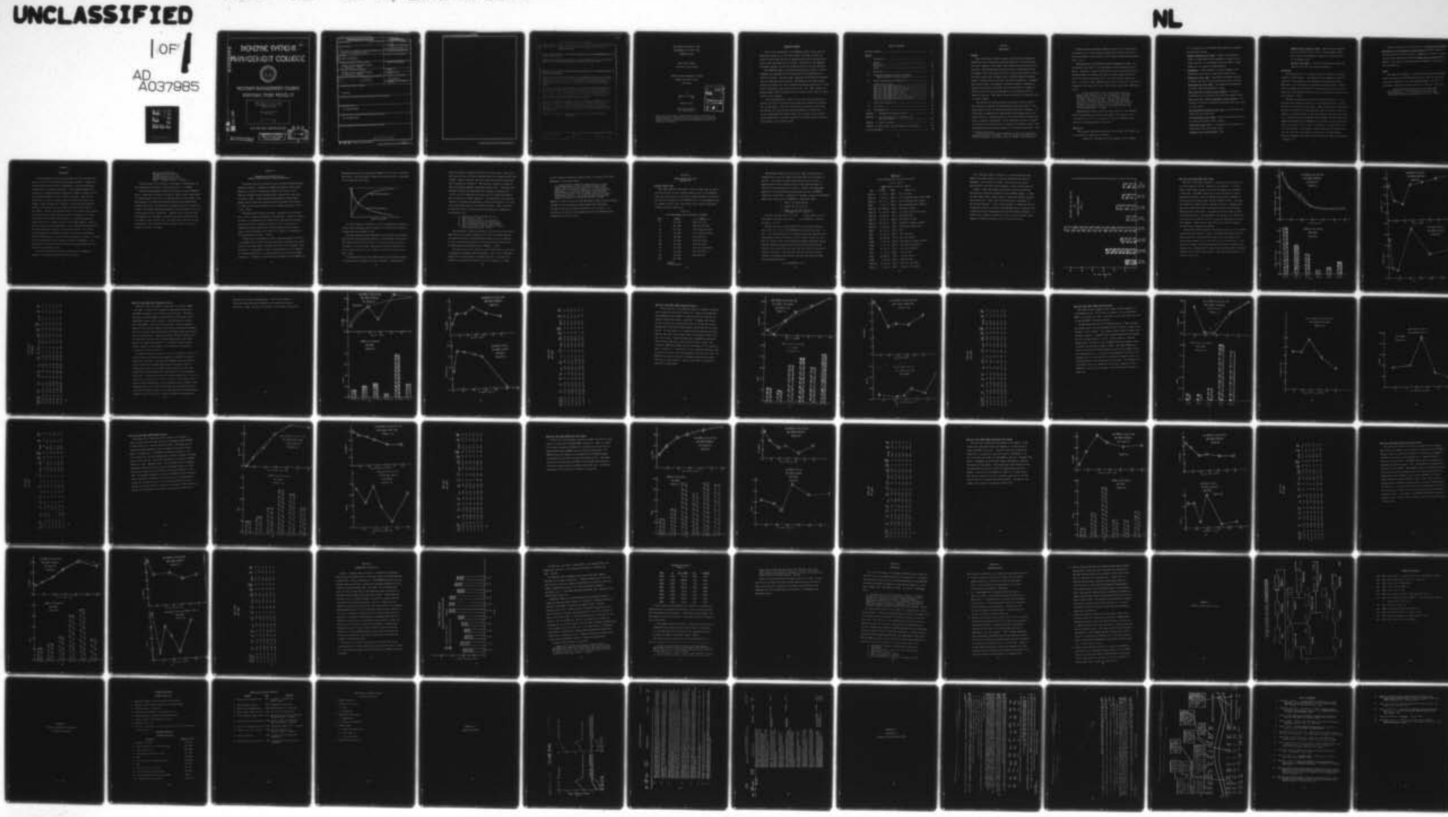

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INDIVIDUAL STUDY PROGRAM

THE EFFECT OF RELIABILITY AND
MAINTAINABILITY ON THE F-14A
TF30P412A ENGINE

STUDY PROJECT REPORT
PMC 76-2

Bruce N. Erickson
LT USN

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: THE EFFECT OF RELIABILITY AND MAINTAINABILITY ON THE F-14A TF30P412A ENGINE.

STUDY PROJECT GOALS:

To examine aircraft engine reliability and maintainability and evaluate their effect on the TF30P412A Engine, its logistics and availability.

STUDY REPORT ABSTRACT:

This report covers a brief history of the TF30P412A Engine and the F-14A's capabilities, the present military specification for aircraft engine testing, analysis of major components of the TF30P412A reliability and maintainability (RAM) and their affect on availability and the logistics support system.

It can be concluded from the report that our present system for developing and testing aircraft engines needs to be improved and that the TF30P412A is a result of that inadequate process. The low operational readiness of the F-14A can in part be blamed on the TF30P412A engine's low RAM. The supply problem has grown due to a proliferating parts problem resulting from numerous Engineering Change Proposals (ECP's).

It is recommended that the Navy: continue to place more emphasis on reliability in the future; establish a Joint Engine Program Office with the Air Force; establish a 1,000 hour mission test for engine development; should give reliability priority over increased technical performance in the development of a new engine; and compare RAM figures for all the turbofan engines.

SUBJECT DESCRIPTORS: Reliability, Maintainability, Aircraft Engines (TF30P412A)

NAME, RANK, SERVICE	CLASS	DATE
Bruce N. Erickson, LT., USN	PMC 76-2	November 1976

THE EFFECT OF RELIABILITY AND MAINTAINABILITY ON THE F-14A TF30P412A Engine

Study Project Report

Individual Study Program

Defense Systems Management College

Program Management Course

Class 76-2

by

Bruce N. Erickson
Lt. USN

November 1976

Study Project Advisor
Mr. Wayne Schmidt

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This study project report represents the views, conclusions, and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management College of the Department of Defense.

EXECUTIVE SUMMARY

After a brief discussion on the TF30P412A engine's history and the operational capability of the F-14A aircraft, the report reviews the current Military Specification for demonstrating aircraft engine performance of newly developed aircraft engines. The effects of the Component Improvement Program, Reliability and Maintainability are also discussed.

The TF30P412A engine is analyzed by the Work Unit Codes of its major components and compared by utilizing Reliability and Maintainability figures and graphs. The major Engine components performance were compared over the three year period analyzed. The Readiness Improvement Status Evaluation Summaries are used to compare the engines contribution to F-14A aircraft degradation over the period July 1975 - July 1976. Engineering Change Proposal (ECP) incorporation and its affect on the logistics support system is also analyzed.

It was concluded that in order to cure a proliferating spare parts problem, more effort and money would be required in Research and Development of new engines. ECP's will have to be more carefully scrutinized, and the Navy will have to place increasing emphasis on Reliability. It is also recommended that the Navy and Air Force create a Joint Aircraft Engine Program Office, and that a Reliability and Maintainability Analysis be conducted on all turbofan engines.

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

Purpose

The aircraft engine logistic support system has grown excessively complex due to poor reliability and maintainability of aircraft engines over their respective life cycles. Many factors have contributed to this situation, like the dwindling value of the dollar, and austere funding for defense, which have made it difficult to acquire new weapons systems, and obtain supply parts to support them. Excessive Engineering Change Proposal incorporation over the years has been influenced by: inadequate basic engine design, the Component Improvement Program, inadequate Research and Development of engines, and utilizing engines in modern jet tactical aircraft originally developed using principles gained from commercial aviation. These factors have contributed to a monstrous logistic support system.

Poor Reliability and Maintainability achieved on engines require more spare parts, Engineering Change Proposals and spare engines in the supply system in order to achieve the desired operational readiness. As of May 1974, the Department of Defense had invested approximately nine billion dollars in aircraft engines, of which approximately one-third was spent on component improvements. Due to the excessive costs of incorporating ECP's and retrofitting during production the question arises, "Are we developing aircraft engines properly, or is there a better way?" (6:1)

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[1]This notation will be used throughout the report for sources of quotations and major references. The first number is the source listed in the bibliography. The second number is the page in the reference.

The Navy spends approximately $200 million per year in maintaining its inventory of aircraft engines, and about $50 - $75 million per year on the procurement of spare engines to fill logistic and maintenance pipelines. (5:1)

Upon graduation from the Defense Systems Management College, I will be assigned to the Naval Air Systems Command, *Aircraft Engine Logistics* Branch. Therefore, I wanted to understand in more detail how Reliability and Maintainability influence the logistics support system and availability of the aircraft engines used in the F-14A tactical fighter aircraft. In March of 1976, Representative Charles H. Wilson (D - California) commented on the recent loss of an F-14A (probable cause--fuel leak/engine fire.)

> The galling problem is that the TF30 engine has been around since 1959 and is far from a new machine. Pratt and Whitney slightly modified it, but the engine was to be one of several proven, off-the-shelf items to reduce the risk involved in developing the F-14. Instead, this powerplant has just cost the Navy another of its most expensive fighters and nearly the lives of two of its men...Associated fix and inspection procedures are costly in labor hours, flying time and maintenance funds. (10:190)

Representative Wilson's frustration and disbelief in the TF30P412A engine's performance are shared by many people involved with it and illustrate why I think it is important to study the TF30P412A engine Reliability and Maintainability statistics.

Definitions

The following terms and abbreviations will be used in the report and are presented for continuity of thought:

Cumulative - The Mean Flight Hours Between Failure (MFHBF),

etc., calculated over the entire data reported and collected to that point in time.

Elapsed Maintenance Time (EMT) - average time required to complete a maintenance action regardless of number of personnel required. It is synonomous with mean time to repair (MTTR) and is a measure of maintainability.

Maintenance - action necessary to repair equipment to an operational ready status or keep them in that status.

Maintenance Action (MA) - unscheduled maintenance reported on single copy and multi-copy maintenance action form (MAF)

Maintenance Man Hours (MMH) - time expended by maintenance personnel completing maintenance actions.

Mean Flight Hours Between Failures (MFHBF) - a measure of reliability and is synonomous with Mean Time Between Failure.

Mean Flight Hours Between Maintenance Actions (MFHBMA) - the average time between unscheduled maintenance repair work (time in flight hours).

Mean Unscheduled Maintenance Time (Mct) - see EMT, MTTR, also called Mean Corrective Time.

Not Operationally Ready (NOR) - unable to perform mission due to awaiting maintenance (AWM) or supply.

Power Plant Change (PPC) - an engineering change approved for incorporation into an aircraft engine.

Reliability and Maintainability - RAM

Reduced Material Condition (RMC) - The system can accomplish part of its mission, but is not Full System Capable (FSC) due to awaiting maintenance or supply for a particular part of its weapons system.

Work Unit Code (WUC) - a five digit alpha-numeric code which identifies aircraft sub-systems and elements.

Limitations

Failure definition is an important facet of a Reliability and Maintainability (RAM) analysis. The problem must be analyzed for cause, responsibility and prevention, and subsequently documented accurately. Additionally, all three levels of maintenance (organizational, intermediate, and depot) must participate in the documentation effort or else a lower level requirement could be met by sliding the work to the next level of maintenance. (8:13)

The Navy 3M System was utilized for the data collection. It is an extensive data collection system, but it does have some built in inadequacies for the purpose of this report. Additional Work Unit Codes (WUC's) evolved as the engine life increased which made it difficult to maintain continuity in data recording of sub-system elements over the total engine life. The Mean Flight Hours Between Failure (MFHBF) and Mean Flight Hours Between Maintenance Action (MFHBMA) do not consider multiple installations within the aircraft, but this data is usable over a long period of time to indicate trends. I was unable to obtain preventive maintenance hours spent on sub-systems and elements of the engine. The Maintenance, Material, Management (3M) report technical narrative sheets are displayed in Appendix IV.

I wanted to compare the data supplied by the Statistical Calculation And Analysis For The Logistics Of Engine Removals (SCALER) System with the data obtained from the 3-M System. SCALER data is based on aircraft engine removals documented through the Engine Accounting System (EAS). However, I was unable to analyze the data and compare it due mainly to the time constraint.

Scope

This paper will attempt to illustrate the correlation and problem areas of Reliability and Maintainability to the logistics system and operational readiness of the F-14A TF30P412A engine. Mr. Willis J. Willoughby, Deputy Chief of Naval Material for RAM, put it this way,

> A high performance product has little value, even as a deterrent, if it cannot consistently deliver this performance because it is either broken down or breaks down immediately upon being pressed into service. (18:15)

SECTION II

BACKGROUND

In the mid-1960's the Navy was developing the F-111B to assume the role of a fleet air defense and air superiority aircraft. However, the F-111B failed to meet the Navy's requirements for carrier suitability in 1968, and the program was cancelled. A new program designated VFX was won by the Grumman Aerospace Corporation in 1969 for design of a new air superiority fighter for use in fleet air defense. This aircraft would have to be carrier suitable, able to counter the current threat (Foxbat, Flagon, Fishbed, etc., aircraft, cruise missile carrying submarines, and surface ships) and be able to meet the threat into the late 1980's. The Navy also specified that the new aircraft would require a 500 nautical mile combat radius and be able to engage in air combat for two minutes utilizing full afterburner. It also would require a weapon system able to counter a threat in all flight regimes. The F-14A was the outcome of the VFX competition. It was designed using maximum off-the-shelf components developed for the F-111B aircraft. As a result of this philosophy the TF30P412A (present F-14A engine) was developed from the TF30P12A engine in the F-111B by redesigning the nozzles. (4:1203) The TF30 chronological engine history is depicted in Appendix I. The information was supplied by the F-14 Program Management Office and Pratt and Whitney's Washington Office.

The F-14A is capable of carrying a wide variety of ordnance to enable it to accomplish its multi-mission capability:

M61-A1 Vulcan 20MM Cannon
AIM-54A Phoenix Missiles (6)
AIM-7E/F Sparrow Missiles (6)
AIM-9G/M Sidewinder Missiles (4)
Bombs - 14 MK-82, 8 MK-83, or 4 MK-84

The most common mix of missiles is two Phoenix, three Sparrow, and four Sidewinders which gives it the most flexibility. (4:1204)

The F-14A was designed to enhance maintainability on the TF30P412A engine. Ready access for engine inspection, repair and oil replenishment is allowed through installation of clamshell doors on the airframe. More than 80 percent of engine associated maintenance can be accomplished through these doors. Four mechanics can change an engine in three hours. (17:37) The JTF-10A (TF-30) was developed in the late 1950's as the first turbofan engine with an afterburner. (16:734) Since it had ten years of development and improvement, the TF30 engine was considered (in the late 1960's) a very low-risk item. The F-14A transitioned to the fleet on October 12, 1972, and did not lose a single aircraft in its first 10,000 flying hours. (4:1205)

SECTION III

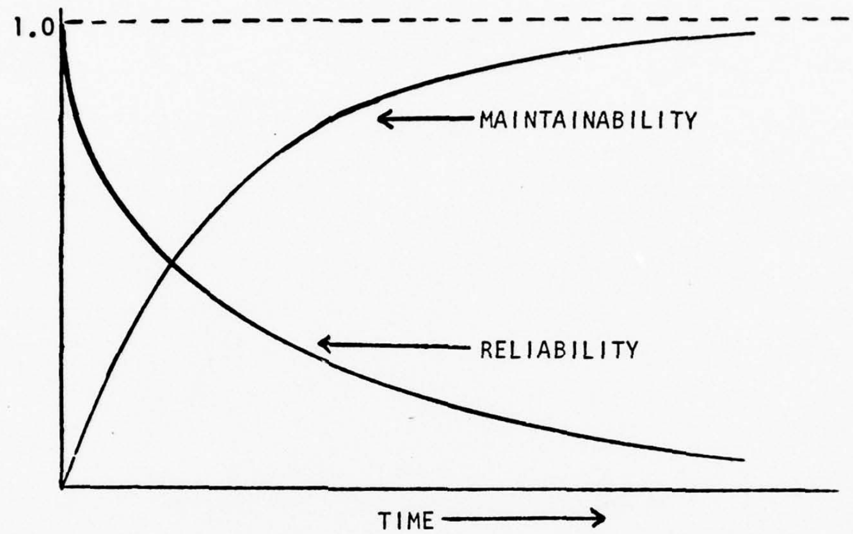
STANDARDS AND DEMONSTRATIONS FOR AIRCRAFT ENGINE RELIABILITY AND MAINTAINABILITY

An aircraft engine will malfunction due to either aerodynamic and/or mechanical problems. Aerodynamic problems are related to basic design defects or the result of mechanical problems (fuel control, etc.). Mechanical problems relate to broken parts, and parts fail due to any of several causes. A part incorrectly manufactured, foreign object damage, applied loads under operating conditions greater than the part will bear, part fatigue and wear out can all affect the useful life of a part. (8:12)

The design specifications must detail information on the environment in which a piece of equipment will be operated. Loads to be applied (G-loads), air temperature, and corrosivity of the service environment must be specified or reliability theory will be of little value. A comprehensive design specification including operating environment, quality, design envelope, and reliability is essential in establishing minimum performance criteria. (3:33)

Reliability is the probability that a system/equipment will perform its intended function within the specified design limitations for a given period of time, when used in the manner for which it was intended. Maintainability is the probability that a system/equipment will be repaired to an operating condition in a given period of time utilizing standard procedures. In Chapter IV, Mean Flight Hours Between Failure (MFHBF) and

Maintenance Man Hours Per Flight Hour (MMH/FH) will be used to illustrate RAM figures. The relationship of RAM with increasing time is illustrated in the normalized chart below.



As time increases the probability of the system/equipment operating without failure decreases and the probability of repairing a malfunction increases with the increase in time.

Aircraft engines have been developed by the military using standard specifications and associated milestones. The Preliminary Flight Rating Test (PFRT) consists of ten cycles of six hours duration on an engine to prepare it for flight test. Engine parts must also complete sixty hours of endurance testing to be judged as successfully completing the PFRT. (9:1)

The Model Qualification Test (MQT) consists of two endurance tests, of 150 hours each, conducted on each of two engines. Each endurance

test will consist of twenty-five cycles of six hours each. Engine parts must also pass the two 150 hour endurance tests to be judged as qualifying. The MQT is used to show that the engine meets specification requirements and is suitable for production. The successful completion of MQT also starts the engines Component Improvement Program (CIP). This means that although the engine has passed MQT and is approved for production, it is still not fully developed and tested, and will require more development to achieve its highest capability. The completion of MQT takes the engine out of Research and Development funding and qualifies it for funding by procurement dollars in the production phase. (6:6) Many areas of additional costs are affected by CIP developments as suggested by the following list:

1. purchase of modification/retrofit kits
2. depot costs to install
3. cost to rework old parts into new design
4. cost of scrapping usable but obsolete parts
5. more frequent maintenance on newer engines
6. cost of investment in engine spares to support early production engines (6:15)

The contractor is required to perform a maintainability/maintenance demonstration on an engine substantially similar to the MQT endurance test engine and have an accumulated engine operating time of 300 hours or more. The primary parameters for assessing engine maintainability are Maintenance Man Hours/Engine Hours (MMH/EH). (9:67)

The qualification tests, specifications and RAM figures must be kept in perspective throughout engine development. Mr. Willis J. Willoughby (Deputy Chief of Naval Material for RAM) wrote that in the past the reliability requirement has not been tied to the design of a system

but was linked to surpassing a numerical goal at the end of Full Scale Development. He further stated,

> More typically reliability "demonstration" is highly questionable because of test conditions and sample sizes chosen. When only numerical reliability is specified as a requirement, it is used too often as an illusionary hurdle to be overcome by any means available other than fundamental design considerations. This is indeed a sad state of affairs since design reliability is the key to successful equipment operation throughout its specified lifetime. (18:13)

Appendix II shows the major Pre MQT development objectives and milestones, and some of the significant Post MQT problem areas (information provided by the Pratt and Whitney Washington, D.C. Office). It is interesting to note that the development cost of the TF30P412A engine through MQT was $ 21.7 million.

SECTION IV

ENGINE PROBLEM AREAS AND RAM ANALYSIS

Current Problem Areas

The F-14A's engine trouble began in April of 1974, with the loss of its first aircraft to first stage fan blade failure in the TF30P412A. Since that time a total of six aircraft crashes have been attributed to the failure of some part of the TF30P412A and it is the suspected cause in a seventh aircraft loss. The F-14A aircraft losses through March of 1976 are shown in Table IV-1:

Table IV-1

F-14 LOSSES/DAMAGE DUE TO ENGINE/FIRE PROBLEMS

A/C	DATE	CAUSE
6*	Jun 1973	AIM-7 Collision
2	May 1974	Hydrazine EPU B-Nut
18	Apr 1974	First Stage Fan Blade
53	Jul 1974	First Stage Fan Blade
8	Sep 1974	Third Fan Disc
43*	Jan 1975	Third Fan Disc**
62*	Jan 1975	Third Fan Disc**
98	Jun 1975	First Stage Fan Blade
17	Aug 1975	Vent Tank Overfill
137*	Oct 1975	Third Fan Disc
127*	Mar 1976	

*Losses
**Probable Cause

The President signed a bill on July 14, 1976, authorizing an unrequested $15 million for research and development of new engines for the F-14. Procurement of either engine (Pratt and Whitney F401 or General Electric F101) planned for the F-14 has been estimated in a GAO report at approximately $1.7 billion. (10:139) The replacement engine will not be available for operational use until the 1980/81 time period, which makes it necessary for the Navy to repair the TF30P412A. Repairs are underway for the TF30P412A in three major areas:

1. Stage 1 fan blade distress
2. Stage 3 fan disc failures
3. Stage 2 turbine seal failures
   (see pages B3 to B4 appendix II)

The Navy estimates that it will cost approximately $86 million to eliminate the problems that have arisen in the TF30P412A in the past two years. (10:138)

The Navy also has initiated a Reliability Improvement Program to improve the reliability of the TF30P412A high failure rate items. In Table IV-2 I have compiled a list of engine sub-systems components that accumulated at least ten failures over the two-year period, Jan. 74 - Dec. 75. Several items listed (combustion chamber, A/B Nozzle Segments Assembly, A/B Nozzle Segments Seal, Main Fuel Control and A/B Fuel Control) show up as high failure rate items and should be analyzed for possible improvement. The individual inherent availabilities were computed, using the actual data from the three year period analyzed, by the following formula:

$$A_i = MFHBF/MFHBF + M_{ct}$$

TABLE IV-2

Engine Elements With Ten Or More Failures

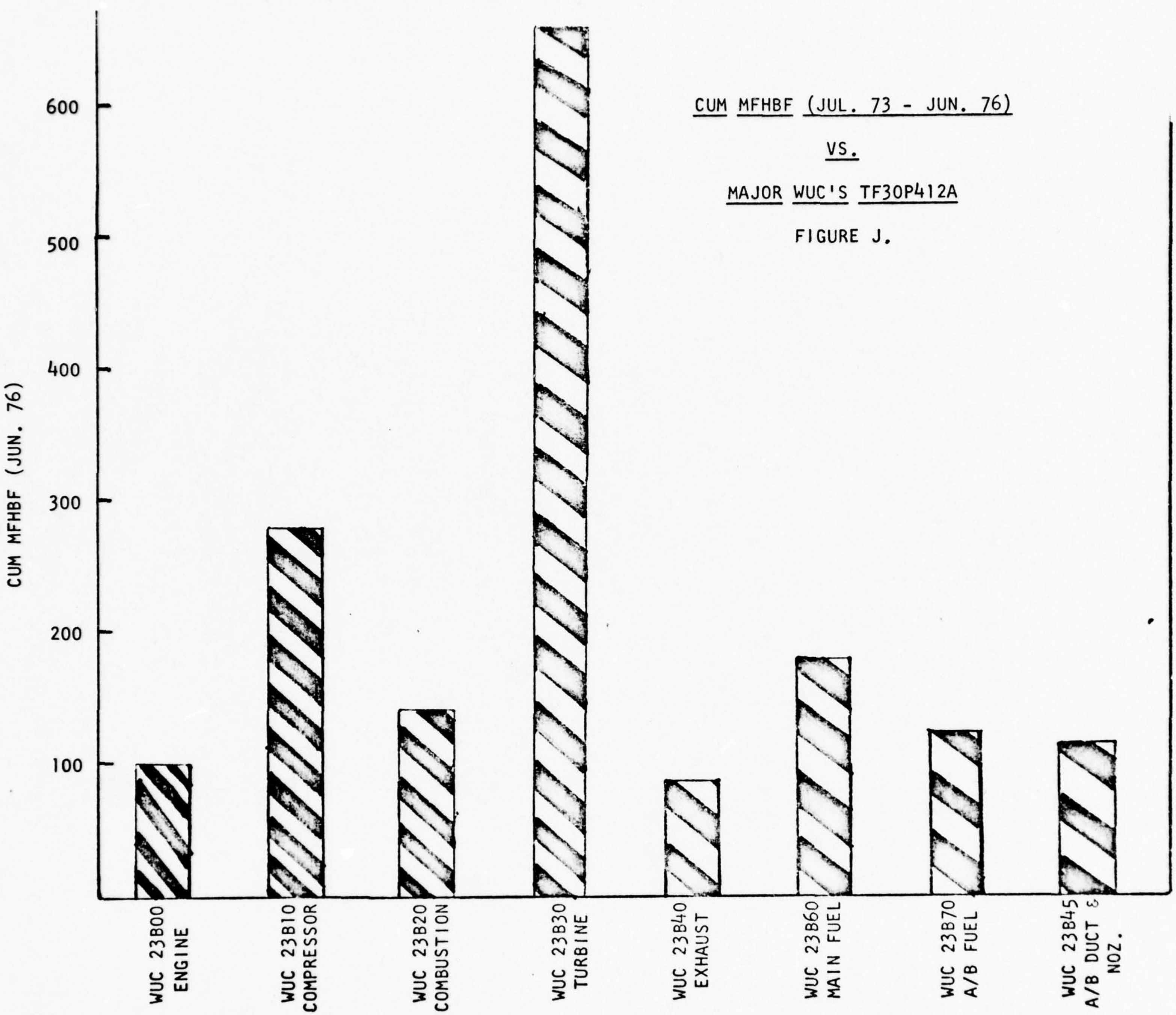
Jan 74 - Dec 75

MFHBF Based On Total FH = 39,971

WUC	Tot Failures	MFHBF	Nomenclature
23B11.00	7 + 8= 15	2664.7	Fan Inlet Case
23B12.10	3 + 7= 10	3997.1	First Stage Compressor Stator Vane
23B1A.10	16 + 1= 17	2351.2	Front Compressor Rotor Blade
23B1B	7 + 4= 11	3633.7	Rear Compressor Rotor Assembly
23B23.00	175 +38=213	187.6	Combustion Chamber
23B31.60	31 + 9= 40	999.2	1st Stage Turbine Stator Vane
23B45.54	55 +18= 73	547.5	A/B Nozzle Seal
23B45.56	8 + 4= 12	3330.9	A/B Nozzle Cylinder
23B45.57	38 +37= 75	533.0	A/B Nozzle Segments Assembly
23B45.58	13 +35= 48	832.7	A/B Nozzle Segments Seal
23B49	20 + 3= 23	1737.9	NOC
23B61	8 + 5= 13	3074.7	Main Fuel Pump
23B62	33 +36= 69	579.3	Main Fuel Control
23B66	2 +21= 23	1737.9	Fuel Nozzle & Support Assembly
23B68	7 + 3= 10	3997.1	Main Fuel System Tubing
23B6A	13 + 4= 17	2351.2	Fuel Filter Assembly
23B71	11 + 9= 20	1998.6	A/B Fuel Pump
23B72	29 +38= 67	596.6	A/B Fuel Control
23B76	9 + 4= 13	3074.7	A/B Fuel Tube
23B77.00	10 +14= 24	1665.5	Hydraulic Fuel Pump
23B77.10	2 + 9= 11	3633.7	Hydraulic Fuel Damper

All of the data listed in Tables IV, V, and the graphs A-L were compiled from data obtained from the Navy Maintenance and Material Management (3-M) Information Systems. This data will be used to analyze each of the major engine components in the following chapters.

Figure J. shows the cumulative reliability (over the three year data period) of each major component of the TF30P412A engine. It does not show recent trends, problem areas, or power plant change incorporations and effects. These items will be discussed in more detail in the following sections. It will also be helpful in reading the following sections to keep in mind that the TF30P412A engine is operating with a 1,000 hour Maximum Engine Operating Time (MOT) between overhauls. It presently has a 225 hour inspection interval in which the basic engine inspection elapsed maintenance time is 15 hours 35 minutes.



CUM MFHBF (JUL. 73 - JUN. 76)

VS.

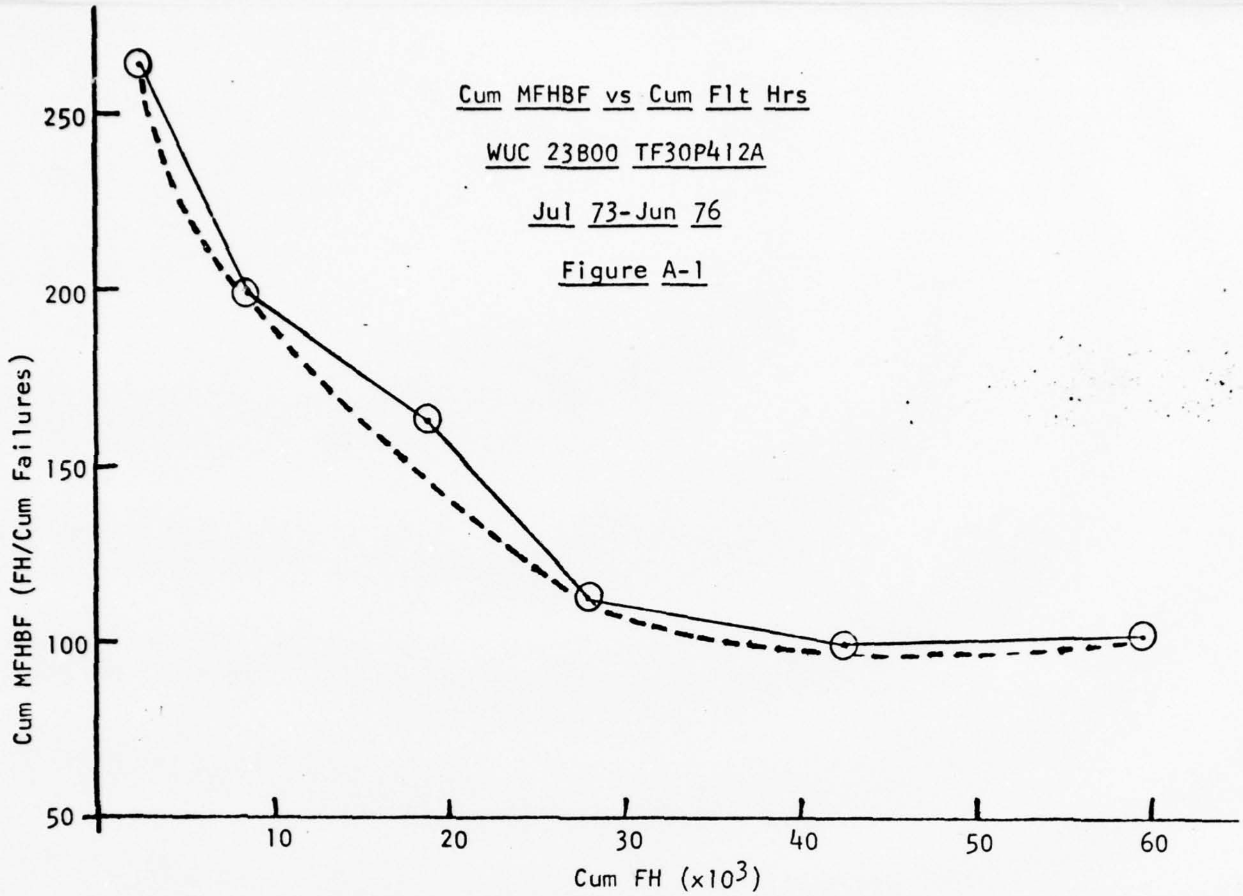
MAJOR WUC'S TF30P412A

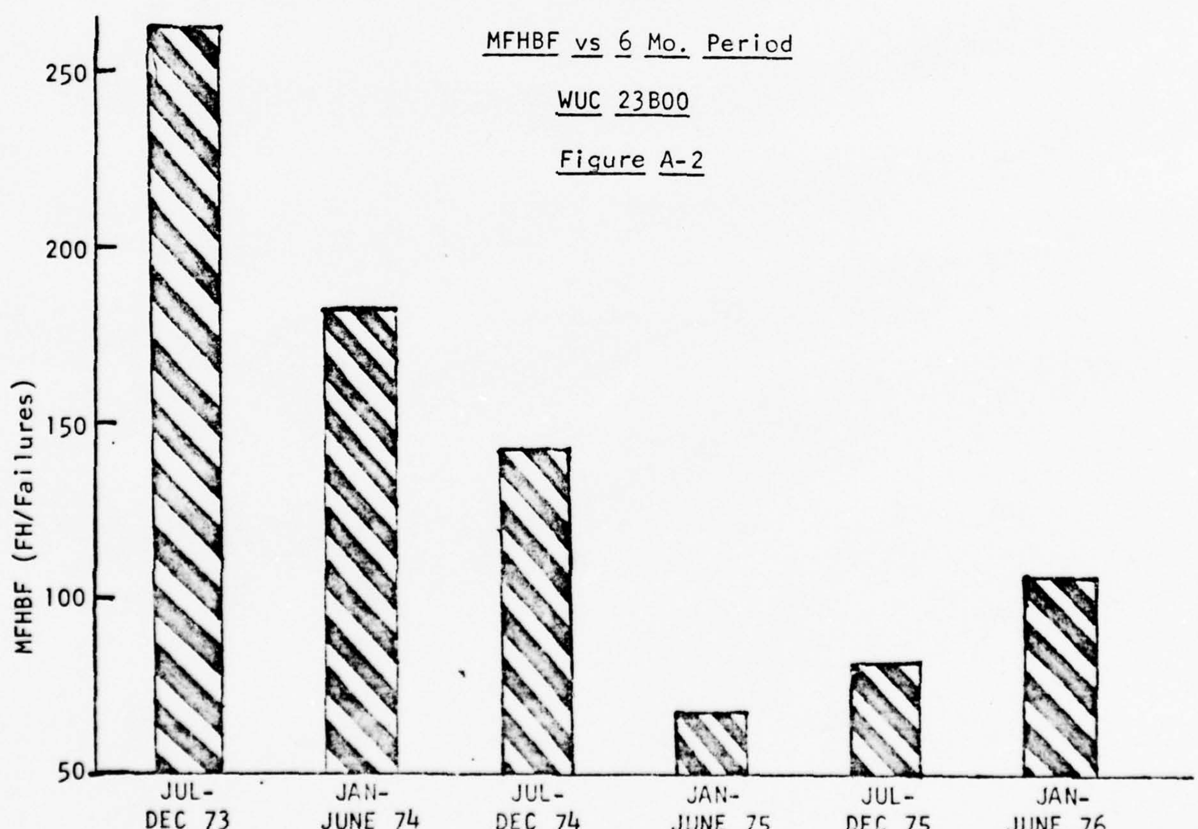
FIGURE J.

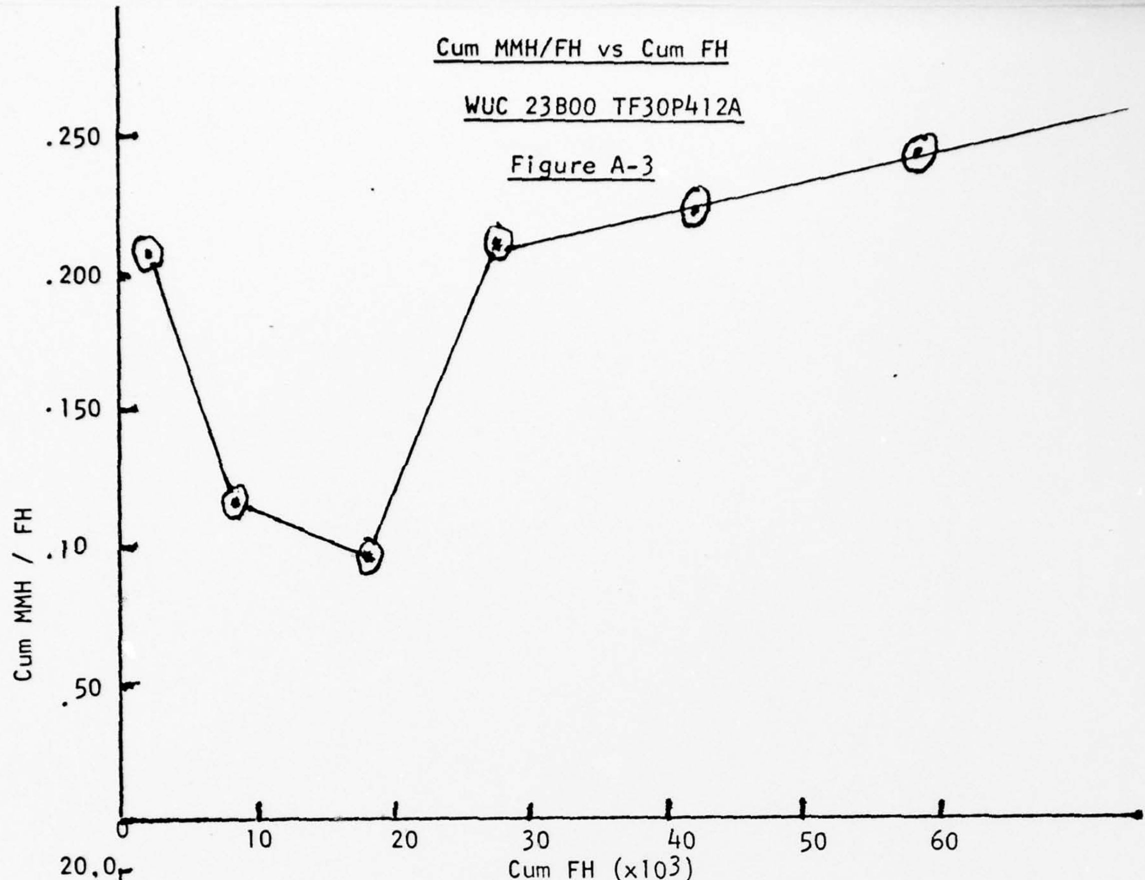
Work Unit Code (WUC) 23B00 TF30 Engine

This WUC is used when the engine is removed from the aircraft due to either component failure, inspections, or overhauls. It is also used to record engine element failure and maintenance not covered by a lower code. The MFHBF (figure A-1) of this WUC (which is closely associated with MTBR - mean time between engine removals) appears to be leveling off at approximately 100 hours between failure. The highest reliability (figure A-2) was obtained in the July - December 1973 time period (about 260 flight hours between failure) and the lowest MTBF occurred in the January - July 1975 time period, about 67 flight hours between failure. The low MFHBF in the January - July 1975 period is partially attributable to the first stage fan blade and third stage disc problems. Three aircraft were also lost in the period January - July 1975 due to these engine problems.

The cumulative MMH/FH appears to be remaining constant at 2.45 MMH/FH (figure A-3) over the past 1½ years. The Elapsed Maintenance Time Per Maintenance Action (figure A-4) has been erratic but appears to be settling down between 14.0 and 16.0 hours per maintenance action. This could be the result of not enough personnel being used on these maintenance actions, inadequate skill levels being assigned, and/or maintenance personnel not learning from experience. The data for the graphs is contained in Table IV-3.


Cum MFHBF vs Cum Flt Hrs
WUC 23B00 TF30P412A
Jul 73-Jun 76
Figure A-1
Cum MFHBF (FH/Cum Failures)
250
200
150
100
50
10
20
30
40
50
60
Cum FH ($x10^3$)

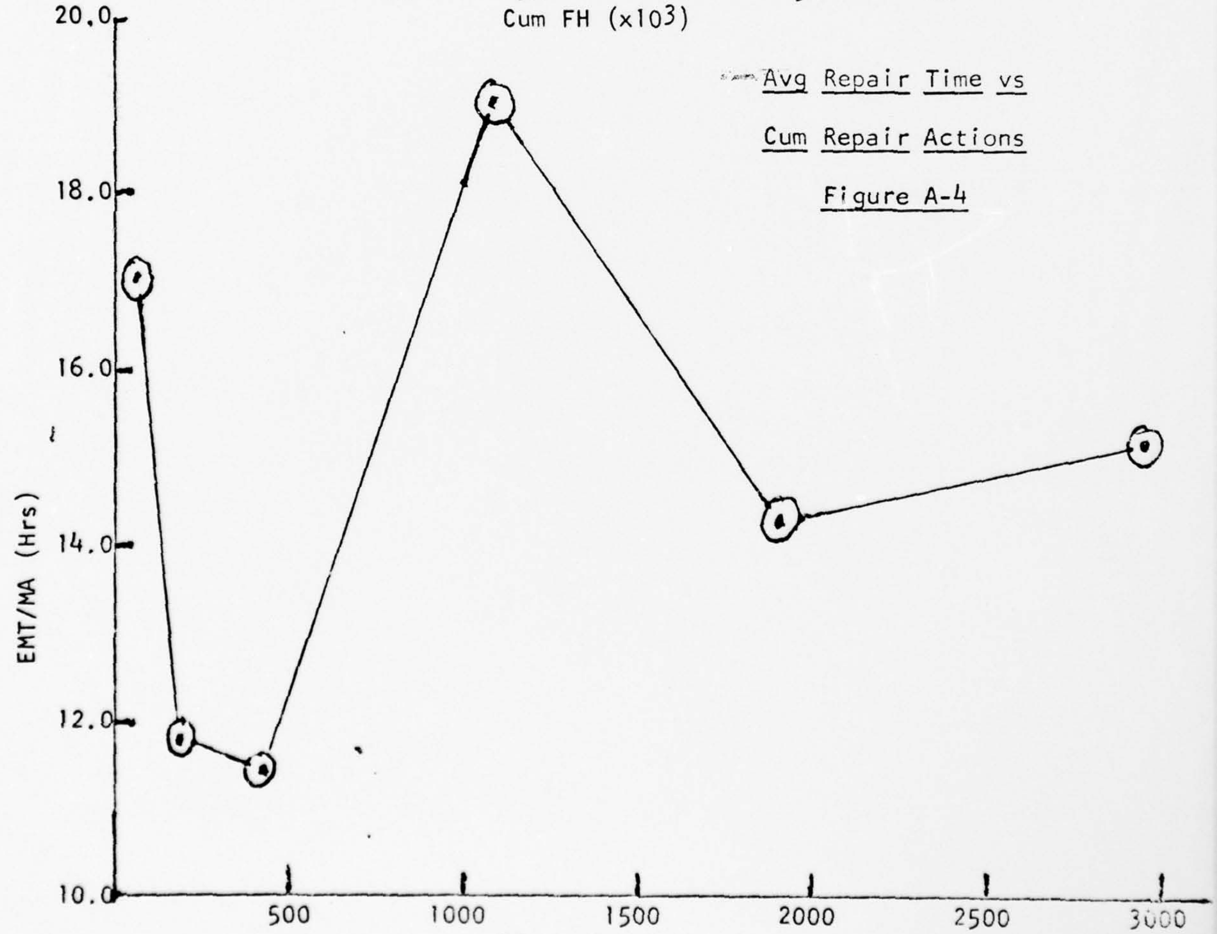

MFHBF vs 6 Mo. Period
WUC 23B00
Figure A-2
MFHBF (FH/Failures)
250
200
150
100
50
JUL-DEC 73
JAN-JUNE 74
JUL-DEC 74
JAN-JUNE 75
JUL-DEC 75
JAN-JUNE 76



Cum MMH/FH vs Cum FH

WUC 23B00 TF30P412A

Figure A-3



Avg Repair Time vs

Cum Repair Actions

Figure A-4

Table IV - 3

WUC 23B00

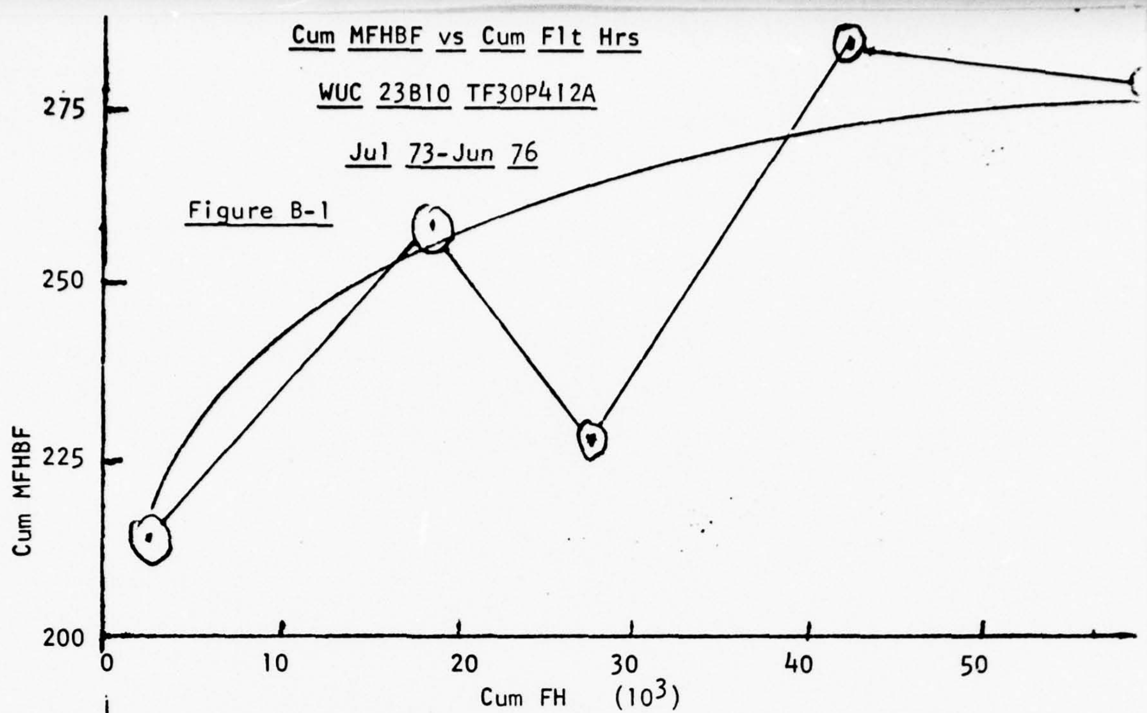
23B00 WUC TF30 Eng	Total FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Tot Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	68	68	4,934	4,934	9	9	263.9	263.9	2.08	2.08	34.9	72.6	17.3
Jan-Jun 74	6,375	8,750	129	197	5,327	10,261	35	44	182.1	198.9	0.85	1.17	49.4	41.3	11.8
Jul-Dec 74	9,886	18,636	219	416	7,737	17,998	70	114	141.2	163.5	0.78	0.97	45.1	35.3	11.5
Jan-Jun 75	9,178	27,814	675	1091	40,568	58,566	134	248	68.5	112.2	4.42	2.11	13.6	60.1	19.1
Jul-Dec 75	14,532	42,346	814	1905	36,219	94,785	179	427	81.2	99.2	2.49	2.24	17.9	44.5	14.3
Jan-Jun 76	16,995	59,341	1045	2950	50,324	145,109	161	588	105.6	100.9	2.96	2.45	16.3	48.2	15.2

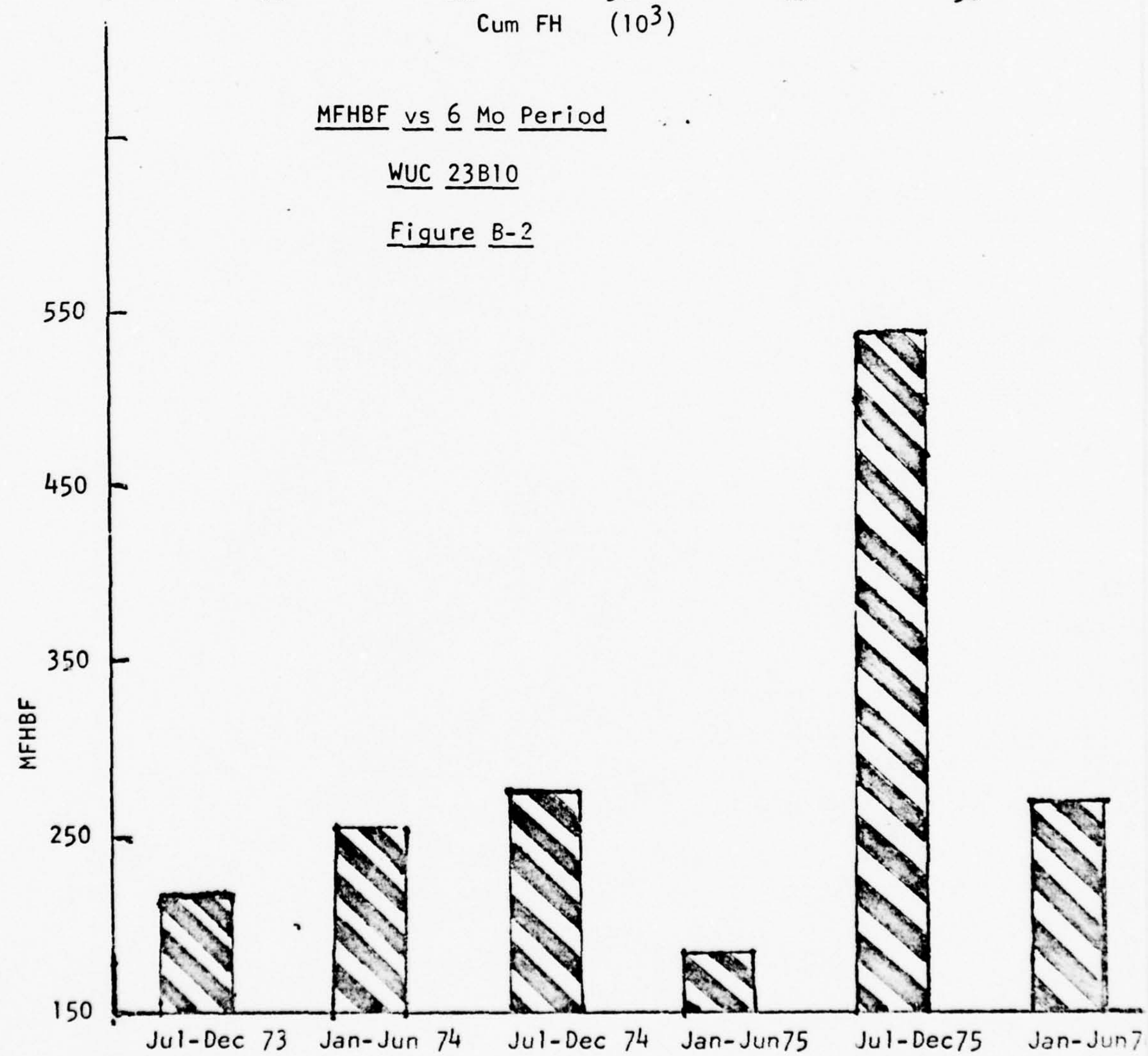
Work Unit Code (WUC) 23B10 Compressor Section

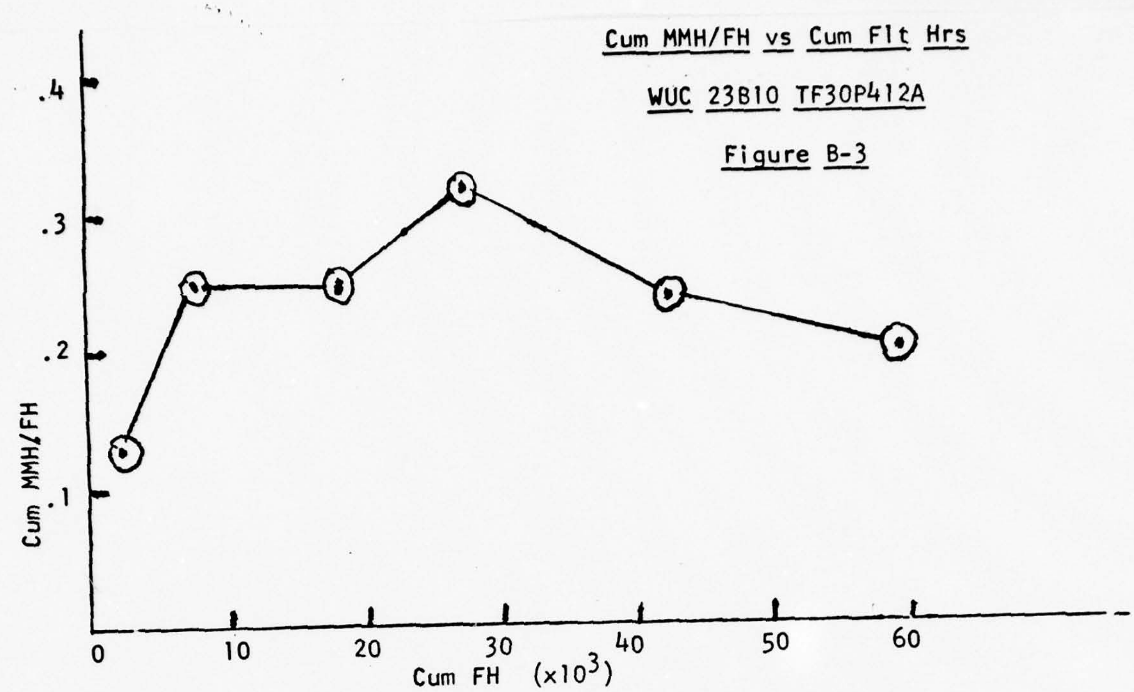
Figure B-1 shows that despite a severe drop in cumulative MFHBF in mid-1975, it rose within six months to approximately 275 cumulative MFHBF and appears to be leveling off at 275 hours. The drop in mid-1975 in cumulative MFHBF is explainable by noticing that the six month MFHBF (figure B-2) for January - June 1975 was at its lowest point (184 MFHBF) in the three years analyzed. The first stage fan blade failures and third stage fan disc failures were dominant problems. The first stage fan blade failures were attributed to heat stress corrosion during fabrication. Power Plant Change - 438 was issued to retrofit the engine fleet with newly designed higher quality fan blades. Revision A to Power Plants Bulletin - 57 provided a one-time eddy-current inspection of fan blades in installed engines to check for intergranular corrosion cracking.

The MMH/FH (figure B-3) rose to a high of .32 MMH/FH at 27,814 cumulative flight hours and has since dropped to .20 MMH/FH after 59,341 cumulative flight hours. The high rate of MMH/FH again was probably a result of Power Plant Changes 438 and 439, an excessive number of fodded engines due to faulty blades, and/or excessive air seal wear, and QEC (quick engine change) Kits received without all the necessary accessories. The average maintenance time/maintenance action (figure B-4) remained high (approximately 8.0) until after about 425 repair actions, when the elapsed maintenance time per maintenance action (EMT/MA = MTTR) decreased rapidly to a little over two hours per maintenance action at about 750 maintenance actions. This graph suggests that the maintenance personnel became familiar with the repair methods and procedures and

and their skill level increased greatly. This is also evident in Figure B-5 which shows that the MMH/FH to be decreasing since the early part of 1975. The data for the graphs is contained in Table IV-4.


Cum MFHBF vs Cum Flt Hrs
WUC 23B10 TF30P412A
Jul 73-Jun 76
Figure B-1
275
250
225
200
Cum MFHBF
0
10
20
30
40
50
Cum FH (10^3)


MFHBF vs 6 Mo Period
WUC 23B10
Figure B-2
550
450
350
250
150
MFHBF
Jul-Dec 73
Jan-Jun 74
Jul-Dec 74
Jan-Jun75
Jul-Dec75
Jan-Jun7


Cum MMH/FH vs Cum Flt Hrs
WUC 23B10 TF30P412A
Figure B-3
.4
.3
.2
.1
Cum MMH/FH
0
10
20
30
40
50
60
Cum FH (x10³)

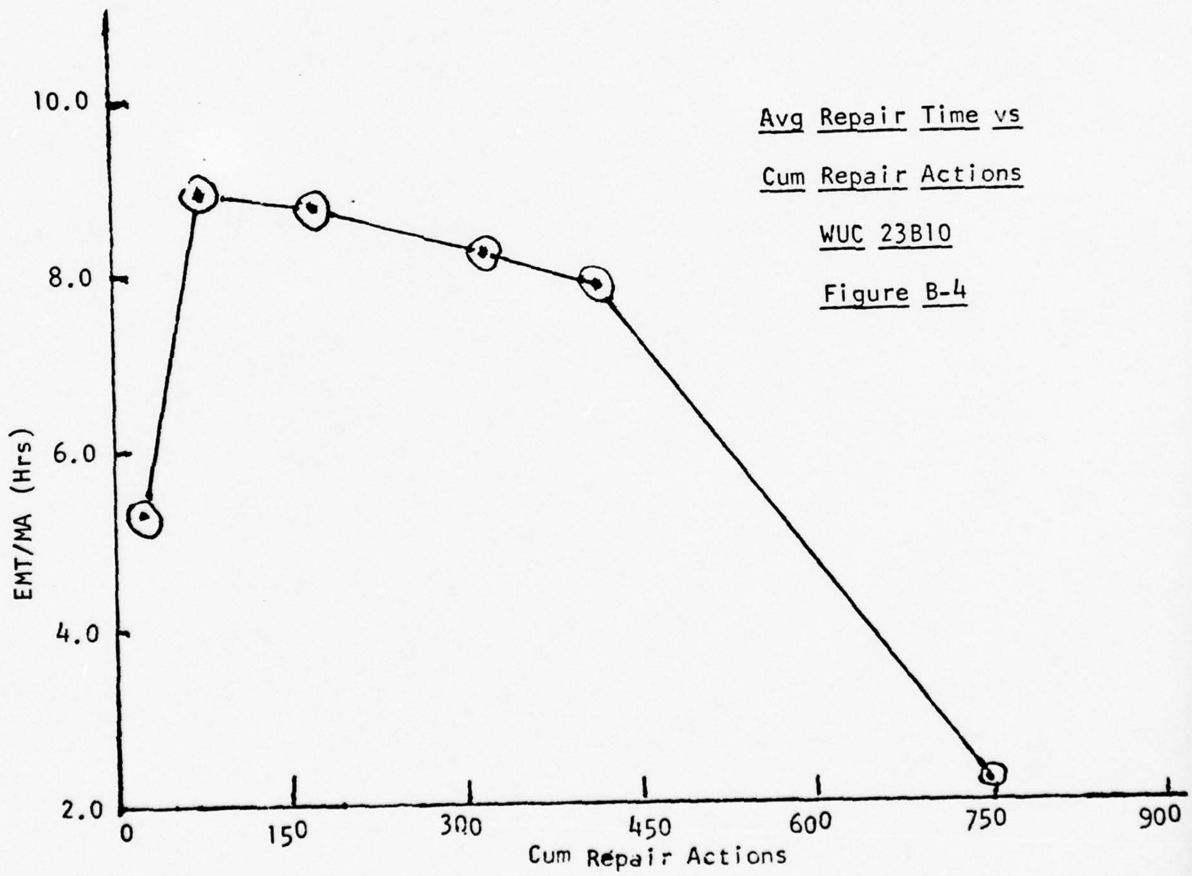

Avg Repair Time vs
Cum Repair Actions
WUC 23B10
Figure B-4
10.0
8.0
6.0
4.0
2.0
EMT/MA (Hrs)
0
150
300
450
600
750
900
Cum Repair Actions

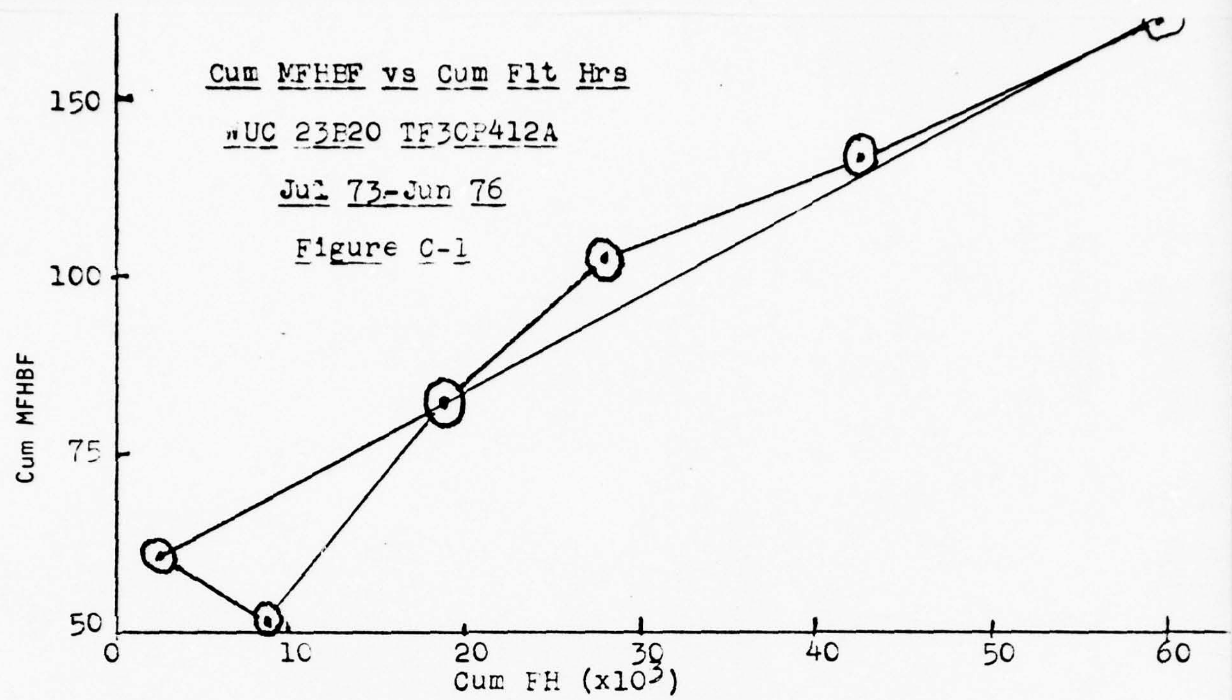
Table IV-4

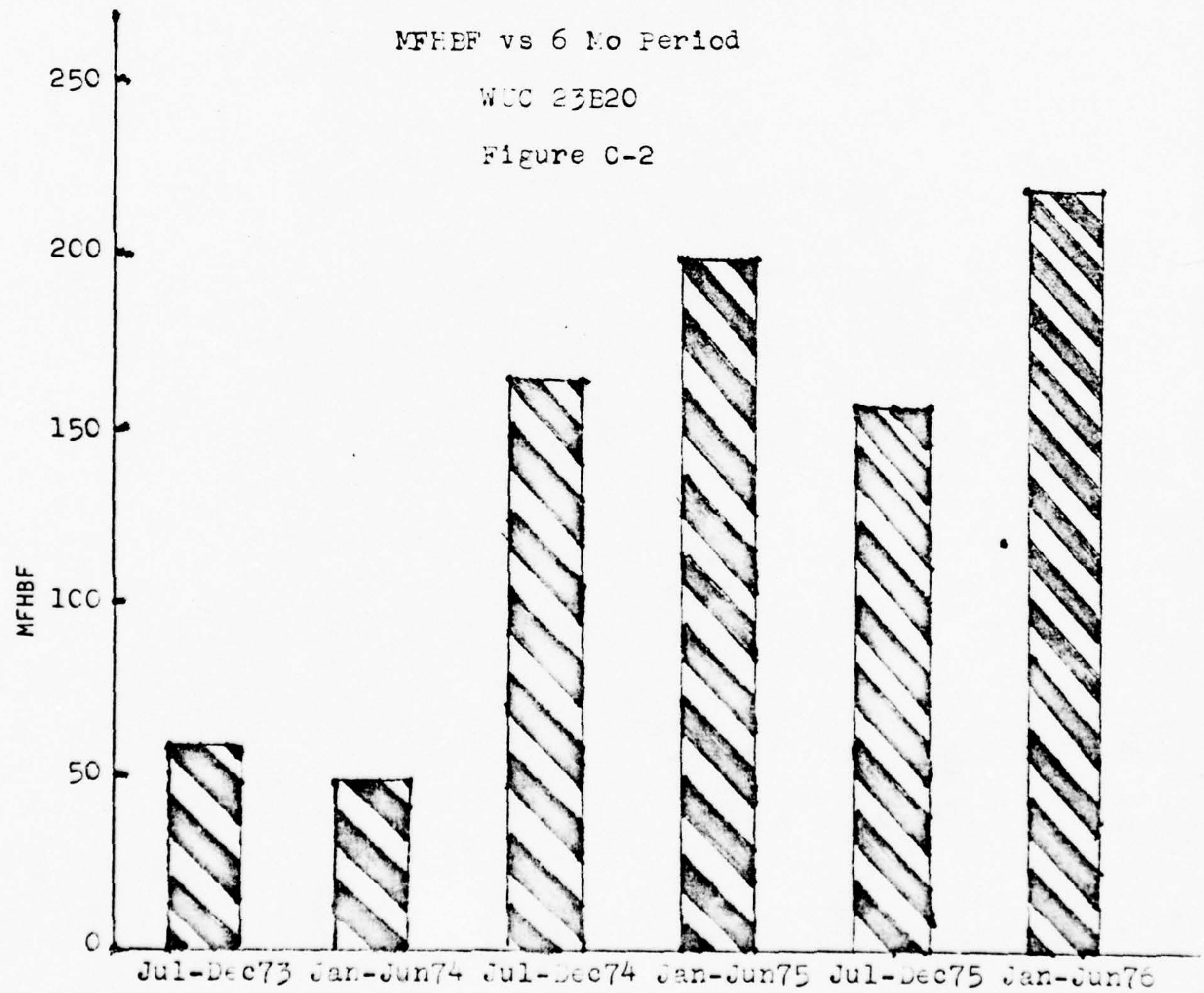
WUC 23B10

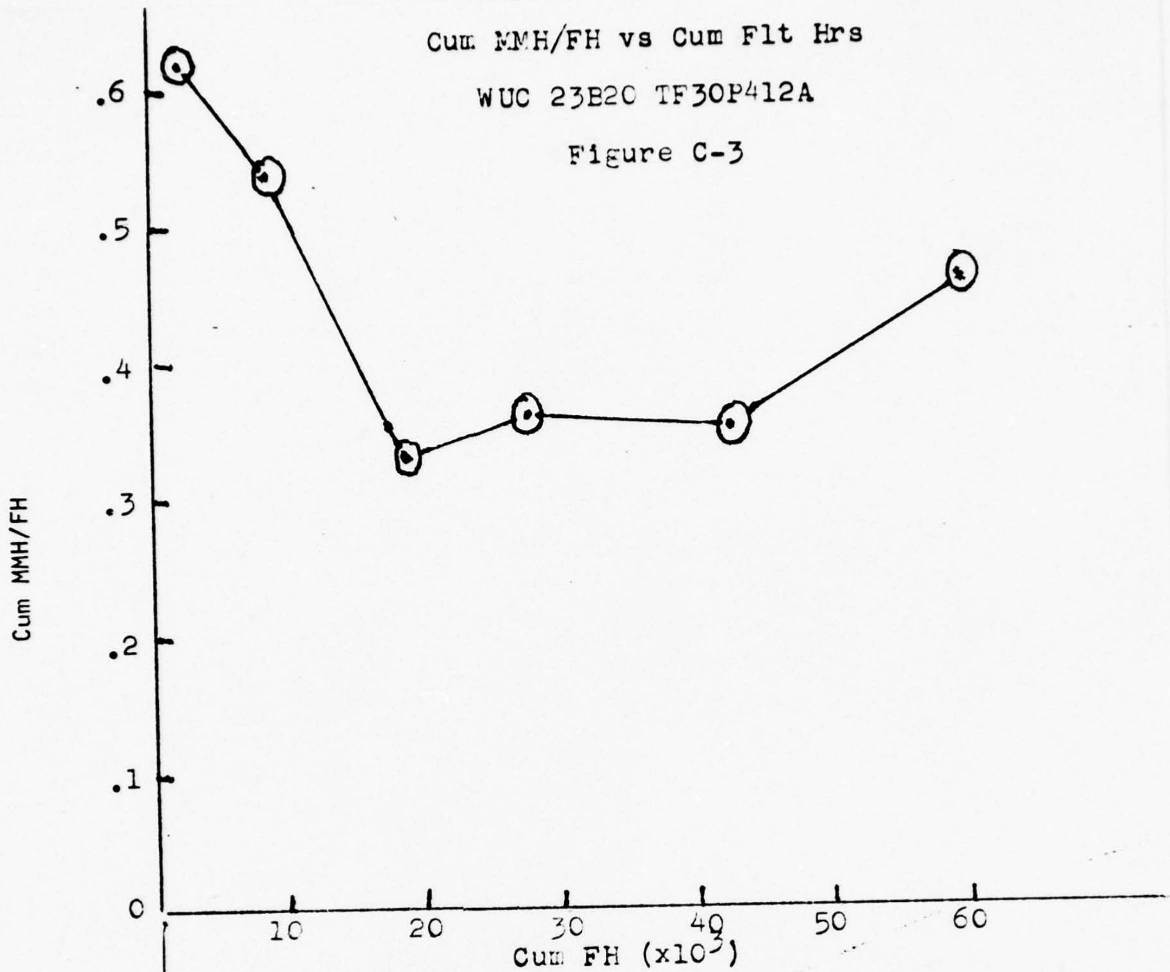
WUC 23B10 Compressor	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	18	18	298	298	11	11	215.9	215.9	.13	.13	131.9	16.6	5.3
Jan-Jun 74	6,375	8,750	57	75	1,879	2,177	25	36	255.0	243.0	.30	.25	111.8	33.0	9.0
Jul-Dec74	9,886	18,636	93	168	2,464	4,641	36	72	274.6	258.8	.25	.25	106.3	26.5	8.8
Jan-Jun 75	9,178	27,814	148	316	4,157	8,798	50	122	183.6	228.0	.45	.32	62.0	28.1	8.3
Jul-Dec 75	14,532	42,346	84	400	1,603	10,401	27	149	538.2	284.2	.11	.24	173.0	19.1	7.9
Jan-Jun 76	16,995	59,341	346	746	1,599	12,000	63	212	269.8	279.9	.09	.20	49.1	4.6	2.2

Work Unit Code (WUC) 23B20 Combustion Section

The reliability of the Combustion Section is steadily increasing with increasing flight hours (Figure C-1). Figure C-2 corroborates this statement as the highest six month reliability figure was obtained in the period January - June 1976. It appears from figures C-3 and C-4 that the maintenance man hours per flight hour and the average repair time have increased greatly during the last six month period. For some reason, it is requiring more maintenance man hours and over twice the time to repair items in this section than in the previous $2\frac{1}{2}$ years. Figure C-3 shows that the MMH/FH was relatively stable (around .035) for $1\frac{1}{2}$ years before climbing to .046. The increase in MMH/FH and EMT/MA, could be the reason for the increasing rate in reliability. A conjecture is that maintenance personnel appear to be taking the time to do the maintenance right the first time. The MMH/FH could decrease again when maintenance personnel have become familiar with the procedures. Data for the graphs is contained in Table IV-5 for WUC 23B20.


Cum MFHBF vs Cum Flt Hrs
WUC 23B20 TF30P412A
Jul 73-Jun 76
Figure C-1
Cum MFHBF
150
100
75
50
0
10
20
30
40
50
60
Cum FH (x10^3)


MFHBF vs 6 Mo Period
WUC 23B20
Figure C-2
MFHBF
250
200
150
100
50
0
Jul-Dec73
Jan-Jun74
Jul-Dec74
Jan-Jun75
Jul-Dec75
Jan-Jun76


Cum MMH/FH vs Cum Flt Hrs
WUC 23B20 TF30P412A
Figure C-3
Cum MMH/FH
.6
.5
.4
.3
.2
.1
0
10
20
30
40
50
60
Cum FH (x10^3)

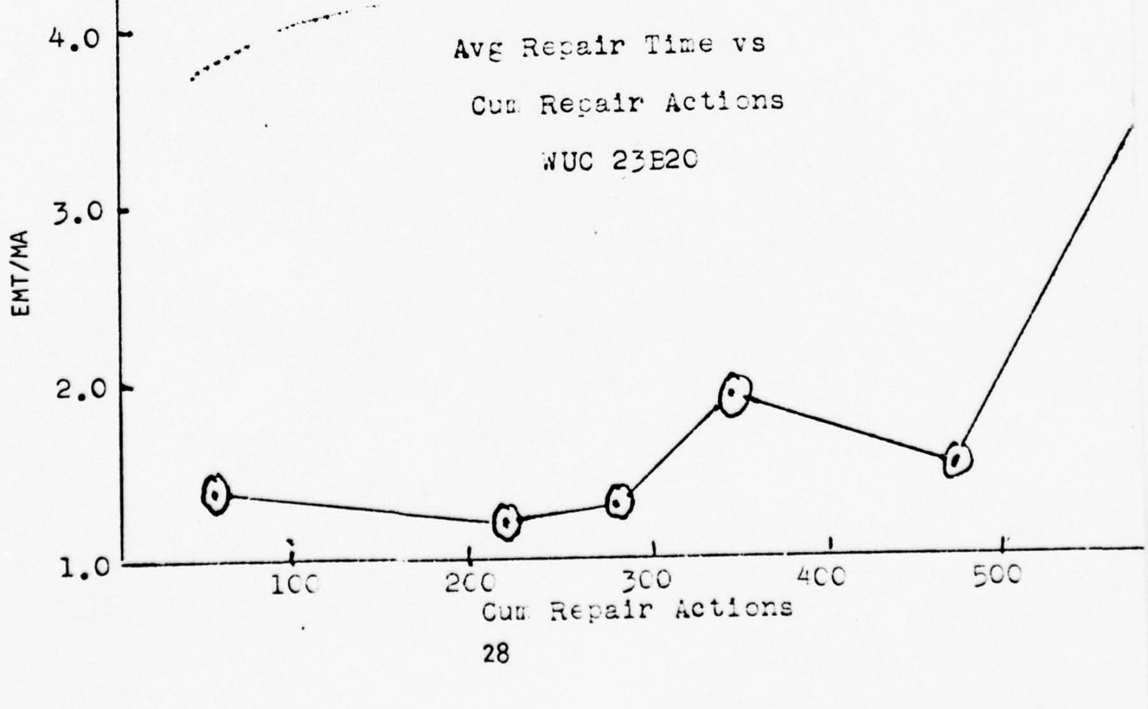

Avg Repair Time vs
Cum Repair Actions
WUC 23B20
EMT/MA
4.0
3.0
2.0
1.0
100
200
300
400
500
Cum Repair Actions

Table IV-5

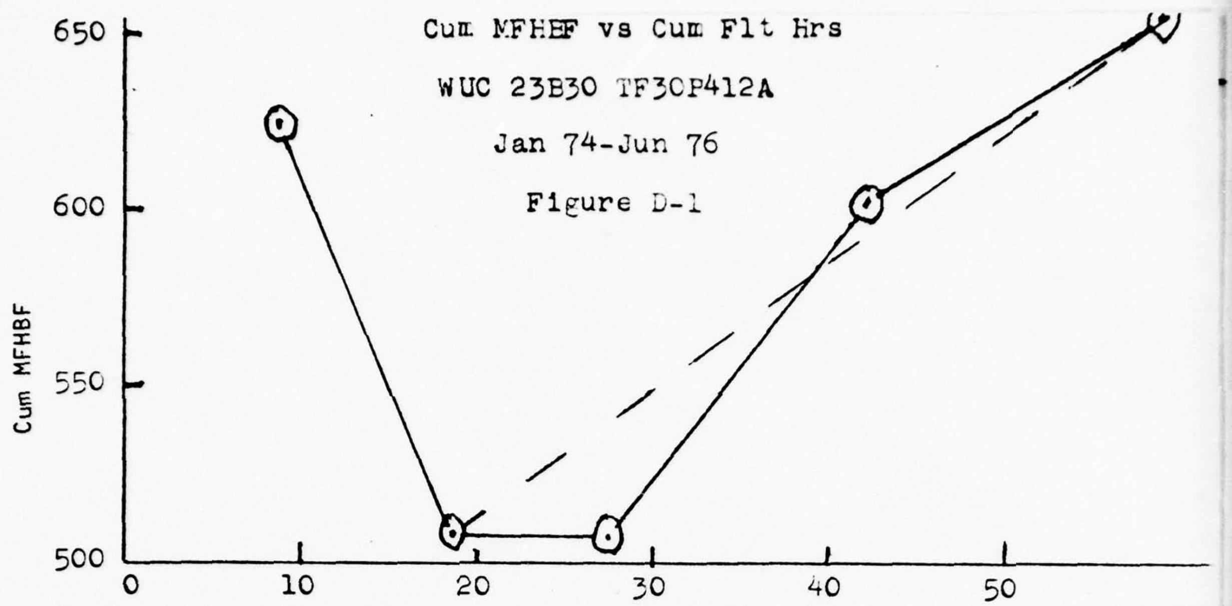
WUC 23B20

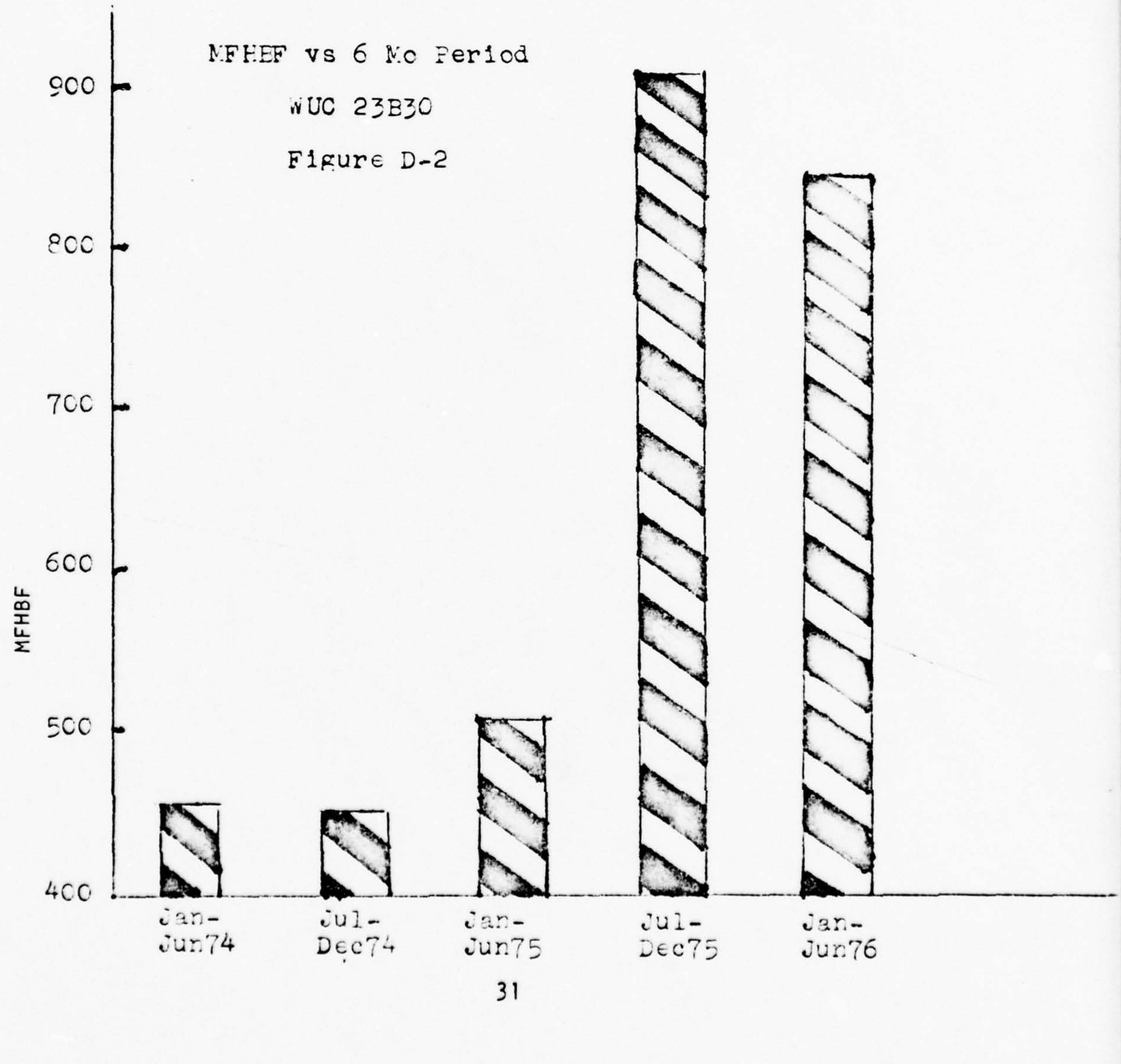
WUC 23B20 Combustion	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	54	54	148	148	39	39	60.9	60.9	.06	.06	44.0	2.7	1.4
Jan-Jun 74	6,375	8,750	160	214	321	469	131	170	48.7	51.5	.05	.05	39.8	2.0	1.2
Jul-Dec 74	9,886	18,636	64	278	152	621	55	225	179.7	82.8	.02	.03	154.5	2.4	1.3
Jan-Jun 75	9,178	27,814	67	345	376	997	46	271	199.5	102.6	.04	.04	137.0	5.6	1.9
Jul-Dec 75	14,532	42,346	128	473	477	1,474	89	360	163.3	117.6	.03	.04	113.5	3.7	1.5
Jan-Jun 76	16,995	59,341	128	601	1,257	2,731	72	432	236.0	137.4	.07	.05	132.8	9.8	3.9

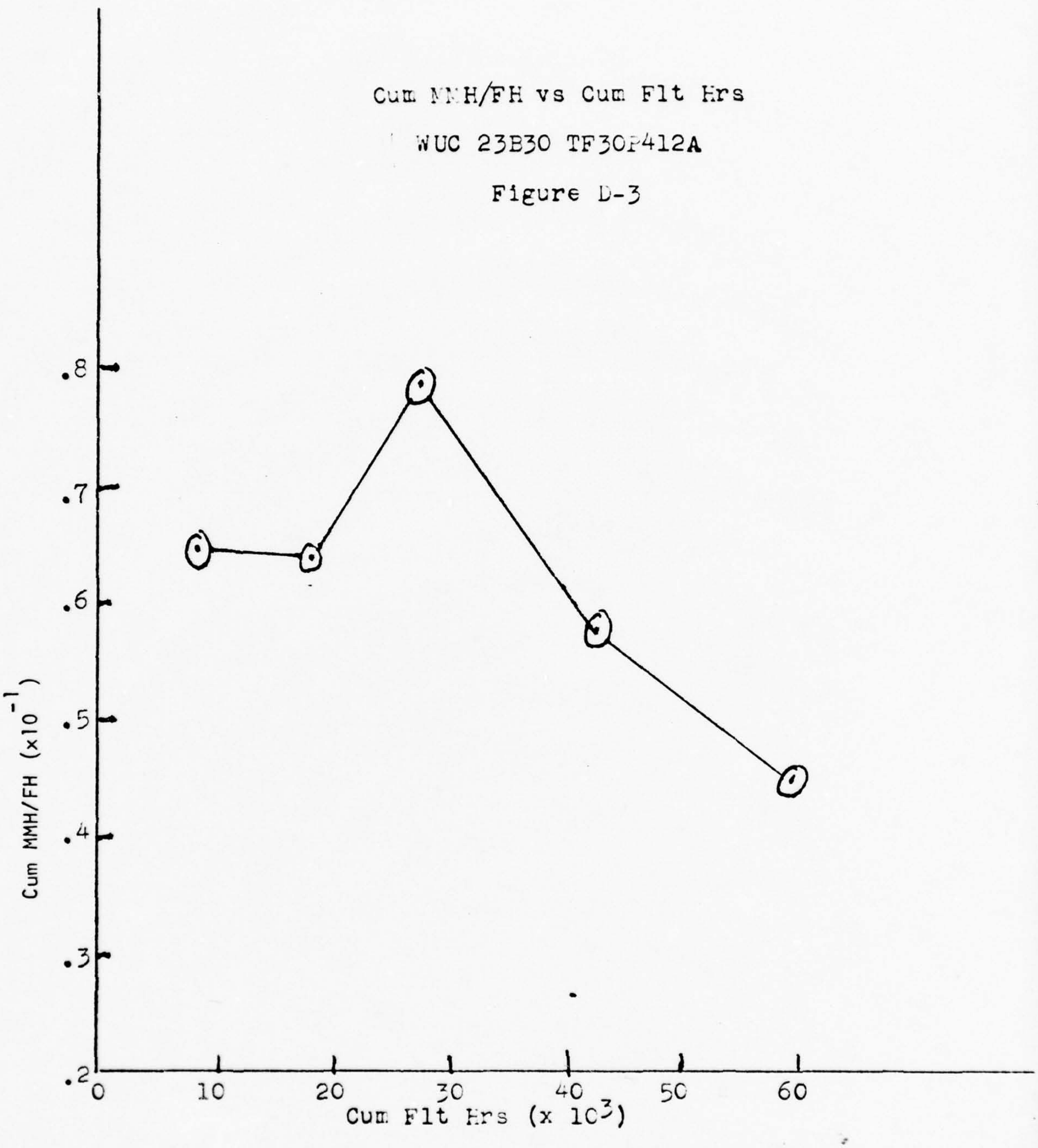
Work Unit Code (WUC) 23B30 Turbine Section

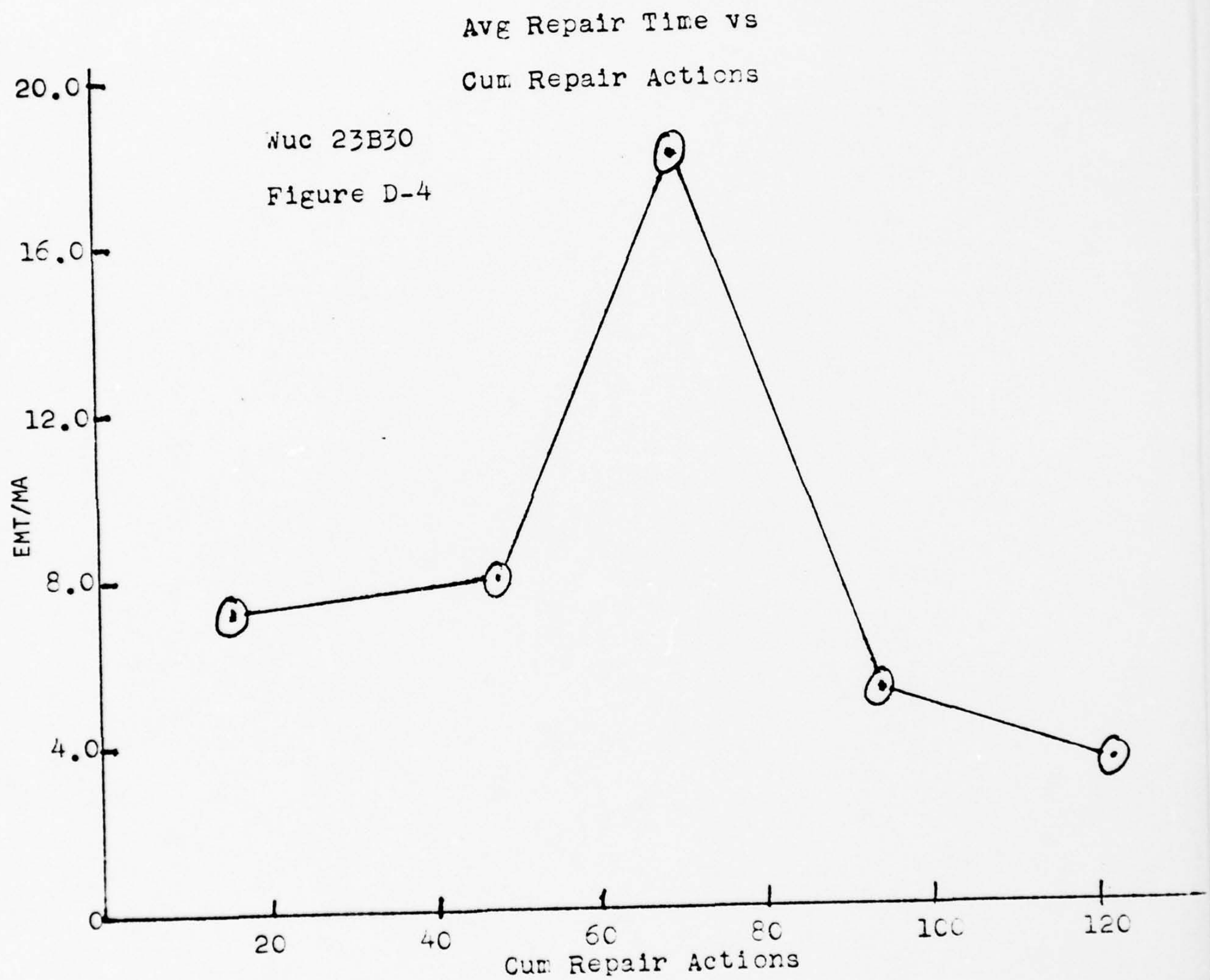
The turbine section appears to be a highly reliable component of the TF30P412A engine. The reliability dropped to just over 500 hour MFHBF in the period July 1974 - June 1975, but has risen since that time to over 650 MFHBF (figures D-1 and D-2).

The maintenance man hours are increasing, but at a lower rate and the average repair time has decreased from over 18 hours to repair after 70 repair actions (January - July 1975) to under 4 hours to repair after 120 repair actions. It appears that maintenance personnel are becoming familiar and experienced in turbine section repairs. The lower average repair time and low rate of MMH/FH (figure D-3) appear to have influenced the continued increase in MFHBF. The lowest MFHBF point figure D-1 also had the highest MMH/FH (figure D-3) and EMT/MA (figure D-4) associated with it. As repair time decreased the reliability increased, which is a positive sign for continued increased reliability and maintainability with the section of the engine. This component has the highest reliability (MFHBF) of all the major components of the TF30P412A. The data for the graphs in this section are contained in Table IV-6.


Cum MFHBF vs Cum Flt Hrs
WUC 23B30 TF30P412A
Jan 74-Jun 76
Figure D-1
Cum MFHBF
650
600
550
500
0
10
20
30
40
50


MFHBF vs 6 Mo Period
WUC 23B30
Figure D-2
MFHBF
900
800
700
600
500
400
Jan-Jun74
Jul-Dec74
Jan-Jun75
Jul-Dec75
Jan-Jun76


Cum MMH/FH vs Cum Flt Hrs
WUC 23B30 TF30P412A
Figure D-3
.8
.7
.6
.5
.4
.3
.2
0
10
20
30
40
50
60
Cum MMH/FH (x10^-1)
Cum Flt Hrs (x 10^3)



Avg Repair Time vs
Cum Repair Actions
Nuc 23B30
Figure D-4
20.0
16.0
12.0
8.0
4.0
0
EMT/MA
20
40
60
80
100
120
Cum Repair Actions

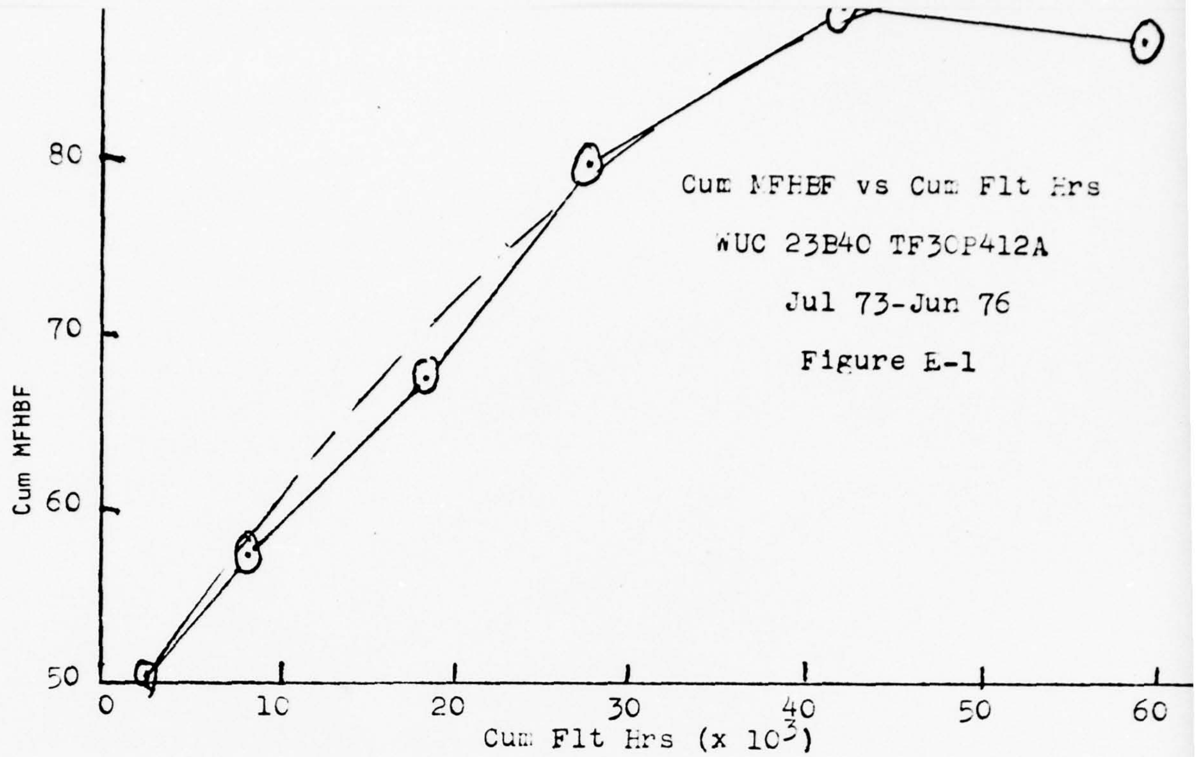
Table IV-6

WUC 23B30

WUC 23B30 Turbine	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jan-Jun 74	6,375	8,750	16	16	418	418	14	14	455.4	625.0	.07	.07	398.4	26.1	7.4
Jul-Dec 74	9,886	18,636	32	48	771	1,189	22	36	449.4	517.7	.08	.06	308.9	24.1	8.0
Jan-Jun 75	9,178	27,814	22	70	1006	2,195	18	54	509.9	515.1	.11	.08	417.2	45.7	18.2
Jul-Dec 75	14,532	42,346	24	94	269	2,464	16	70	908.3	604.9	.02	.06	605.5	11.2	5.3
Jan-Jun 76	16,995	59,341	28	122	234	2,698	20	90	849.8	659.3	.01	.05	607.0	8.3	3.5

Work Unit Code (WUC) 23B40 Exhaust Section

The reliability of the Exhaust Section appears to have been increasing through 1975 and began leveling off at approximately 85 MFHBF in 1976 (figure E-1). Over the period July 1975 - June 1976, the reliability has been decreasing, but will hopefully level off at 85 or begin to increase again. The MMH/FH is decreasing to about a 1 to 4 ratio (figure E-3), yet the average repair time has fluctuated 1.5 hrs/MA about 5.0 hours per MA. The EMT had decreased from 6.8 (July - December 1974) to 3.5 (July - December 1975). This favorable trend in increasing maintenance experience and skill level and decreased repair time, then reversed and jumped up to 6.0 hrs/MA during the period January - June 1976. The decreasing MMH/FH and fluctuating EMT/MA could be influencing the low reliability evidenced in figure E-1 and E-2. Maintenance procedures for this section as well as the elements which make up this section of the engine should be examined for accuracy, content and design. The data for the graphs in this section are contained in Table IV-7.

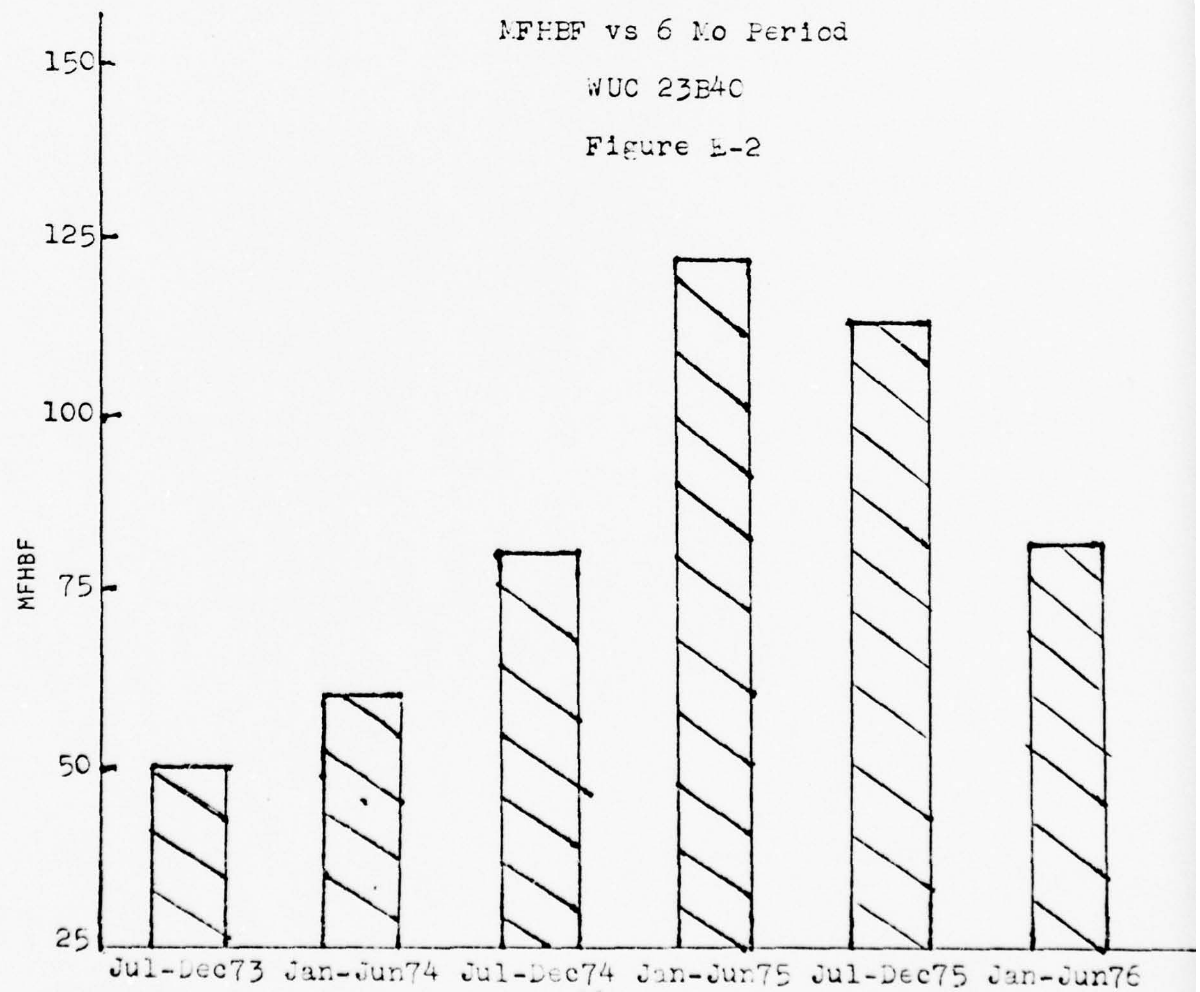


Cum MFHBF vs Cum Flt Hrs

WUC 23B40 TF30P412A

Jul 73-Jun 76

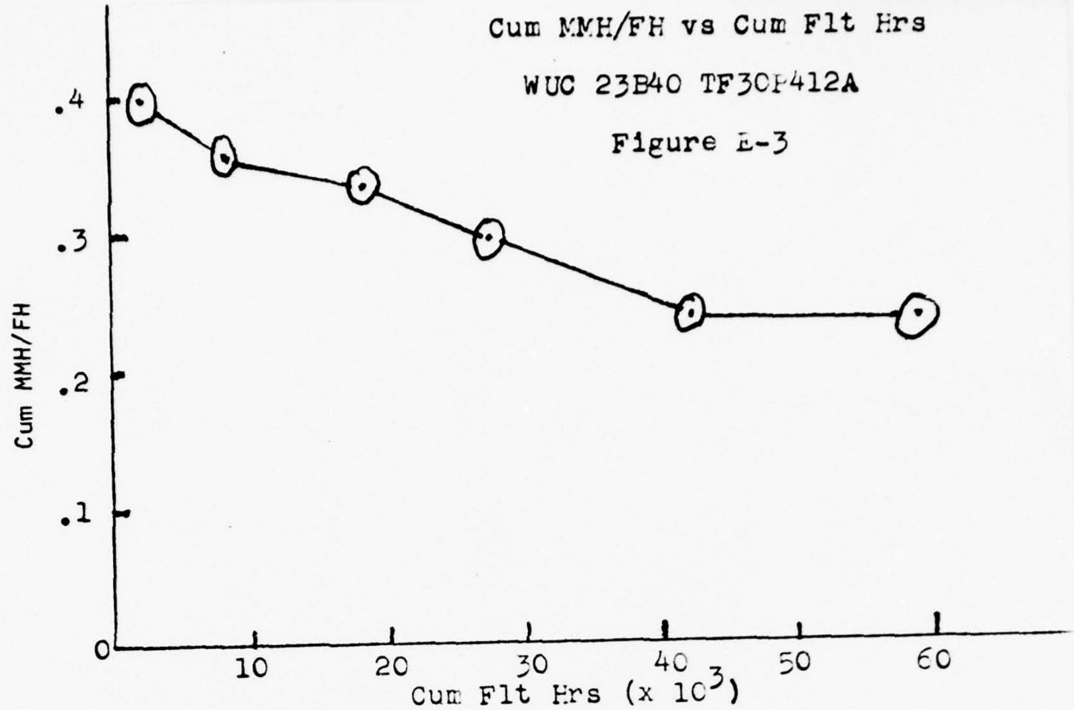
Figure E-1



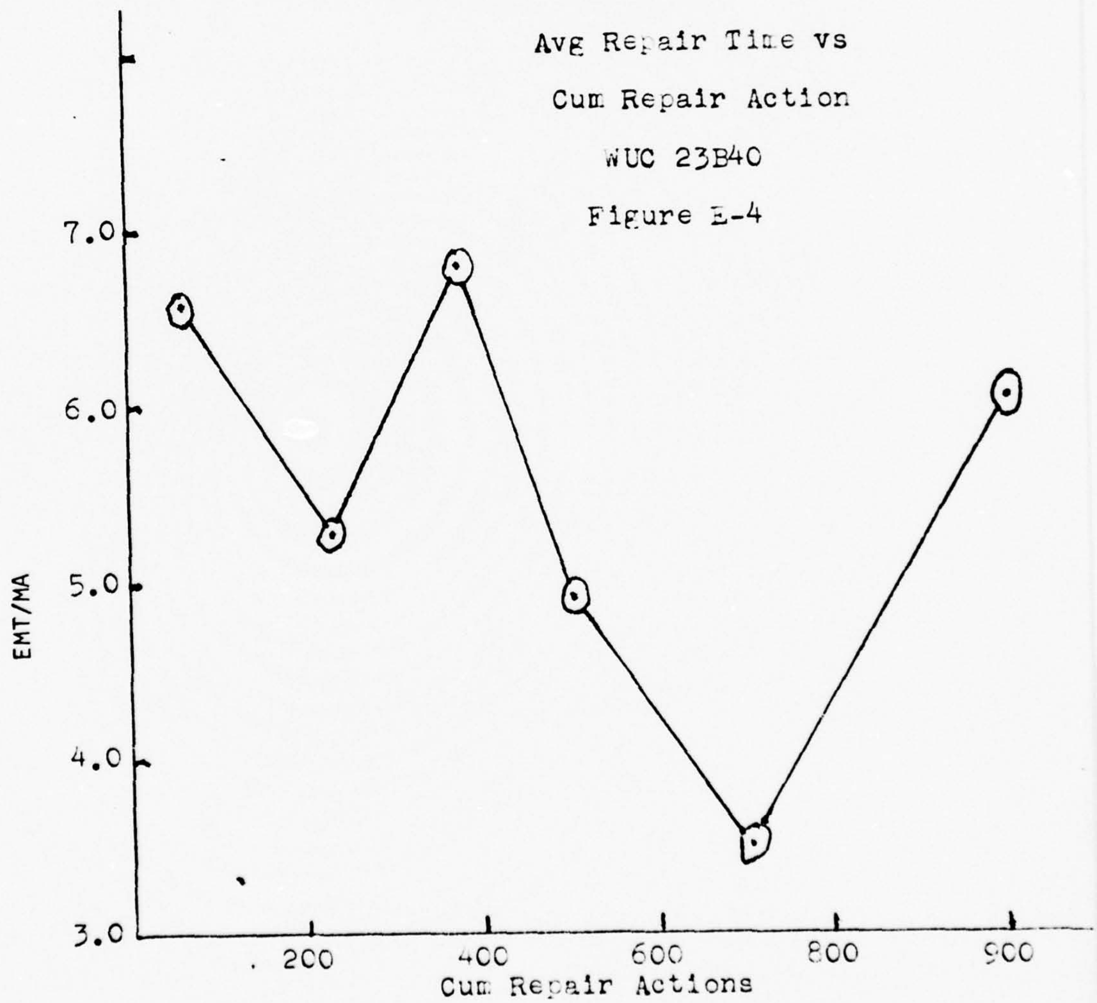
MFHBF vs 6 Mo Period

WUC 23B40

Figure E-2



Cum MMH/FH vs Cum Flt Hrs
WUC 23B40 TF30P412A
Figure E-3
Cum MMH/FH
.4
.3
.2
.1
0
10
20
30
40
50
60
Cum Flt Hrs (x 10^3)



Avg Repair Time vs
Cum Repair Action
WUC 23B40
Figure E-4
EMT/MA
7.0
6.0
5.0
4.0
3.0
200
400
600
800
900
Cum Repair Actions

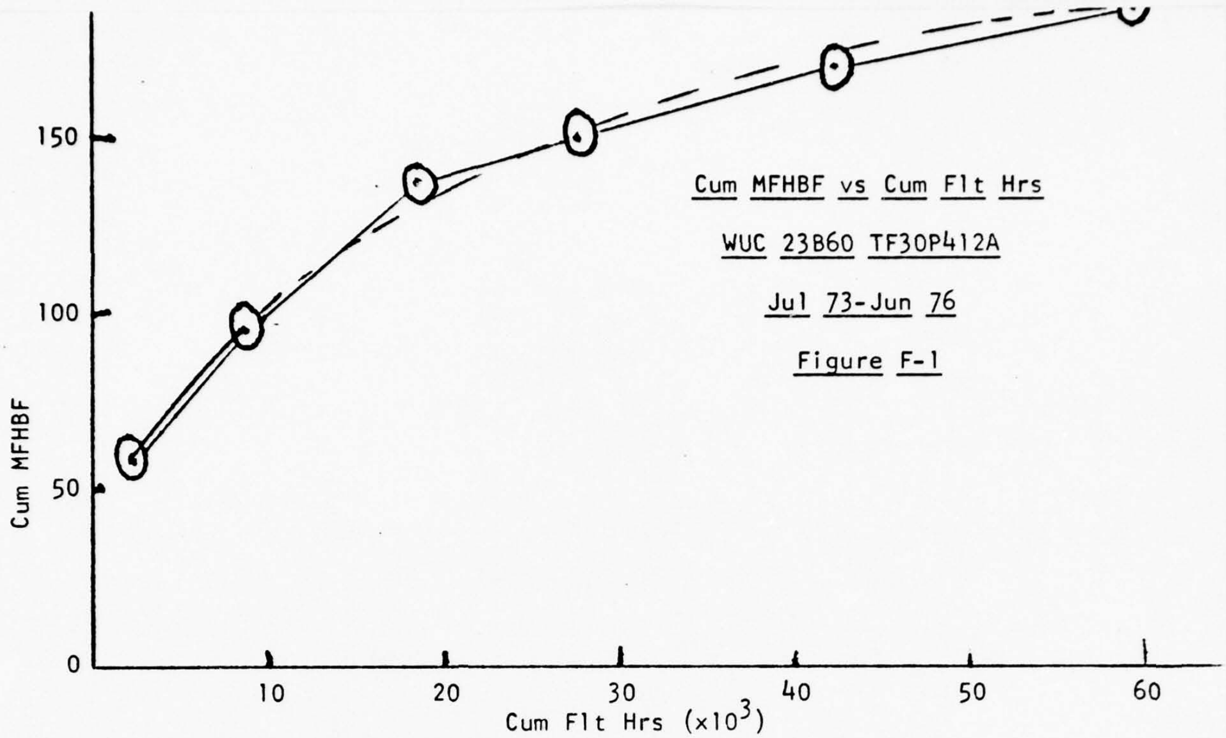
Table IV-7

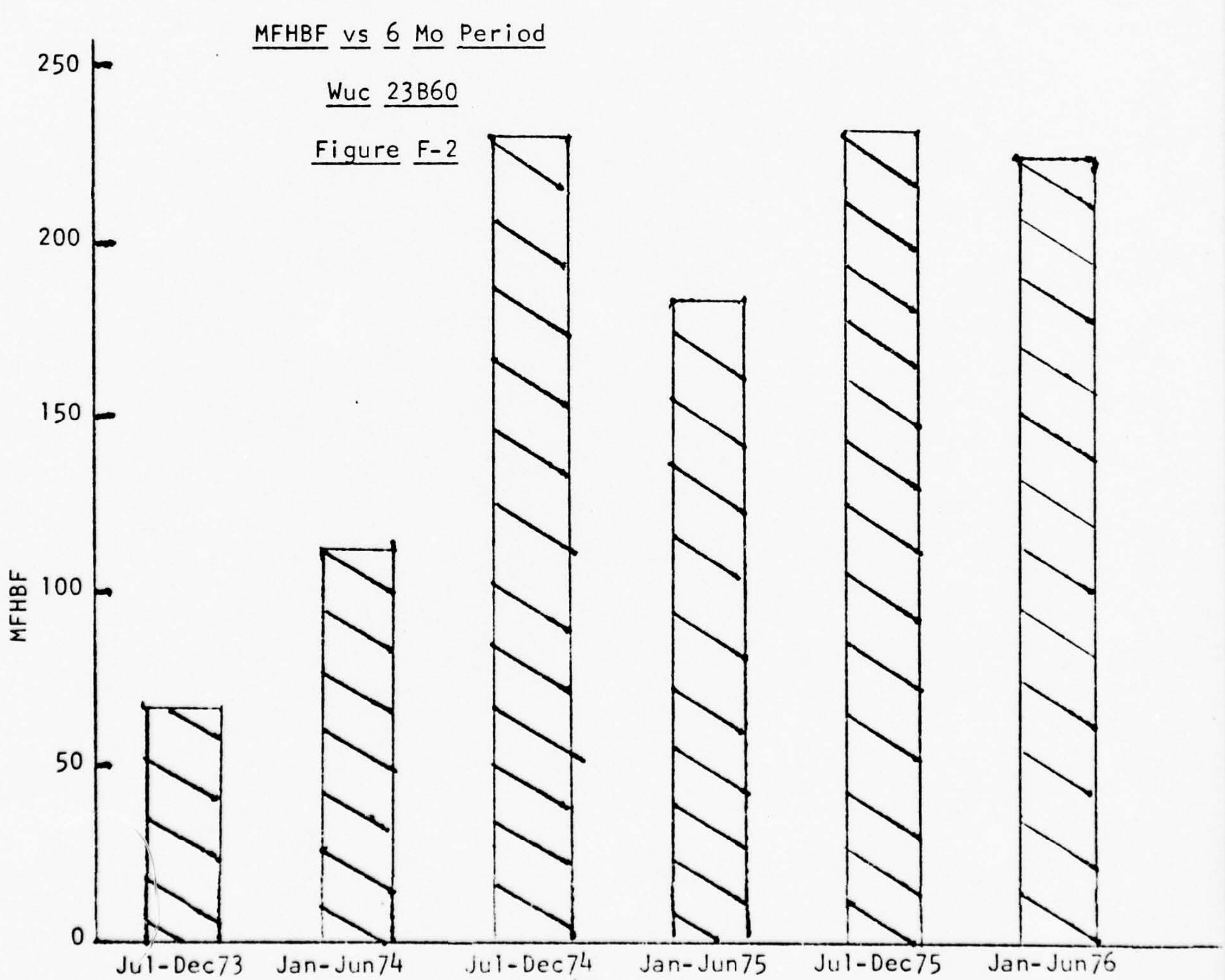
WUC 23B40

WUC 23B40 Exhaust	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Tot Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	65	65	954	954	47	47	50.5	50.5	.40	.40	36.5	14.7	6.6
Jan-Jun 74	6,375	8,750	151	216	2,154	3,108	105	152	60.7	57.6	.34	.36	42.2	14.3	5.3
Jul-Dec 74	9,886	18,636	165	381	3,152	6,260	123	275	80.4	67.8	.32	.34	59.9	19.1	6.8
Jan-Jun 75	9,178	27,814	135	516	2,011	8,271	75	350	122.4	79.5	.22	.30	68.0	14.9	4.9
Jul-Dec 75	14,532	42,346	199	715	1,630	9,901	128	478	113.5	88.6	.11	.23	73.0	8.2	3.5
Jan-Jun 76	16,995	59,341	292	1007	4,098	13,999	207	685	82.1	86.6	.24	.24	58.2	14.0	6.0

Work Unit Code (WUC) 23B60 Main Fuel System

The Main Fuel System appears to have an increasing reliability trend which is leveling off around 200 MFHBF (figure F-1). There is a possibility that the cumulative MFHBF will rise more since the last two six month periods have had MFHBF values of over 220 (figure F-2). The MMH/FH (figure F-3) appears to be decreasing and the EMT/MA appears to be leveling off around 6 hours per maintenance action. The stable reliability and relatively low MMH/FH figures suggest that this section of the engine continues to perform relatively well. The data for the graphs in this section are contained in Table IV-8.

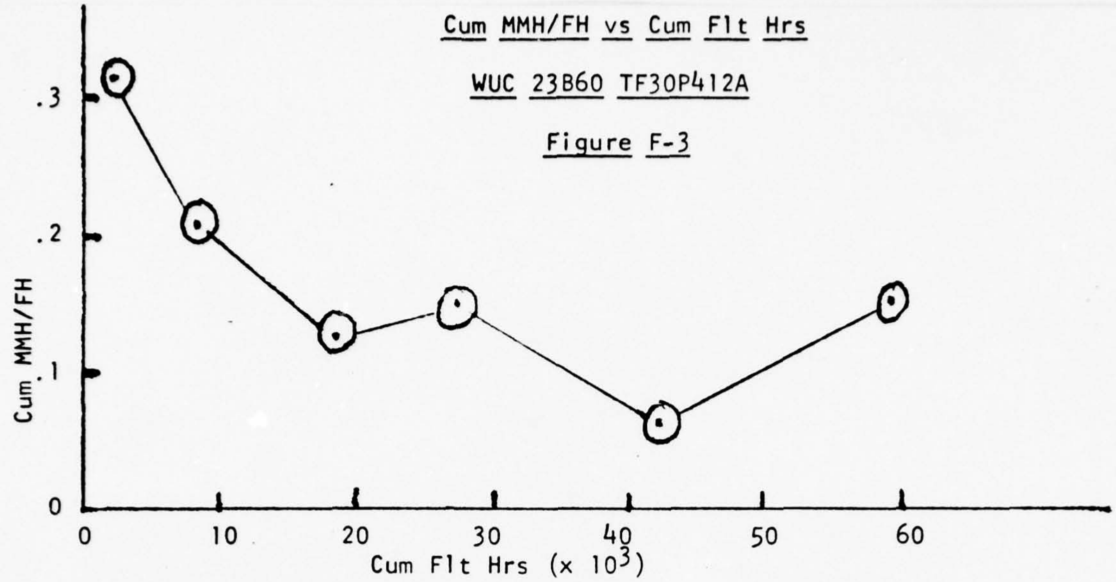

Cum MFHBF vs Cum Flt Hrs
WUC 23B60 TF30P412A
Jul 73-Jun 76
Figure F-1
Cum MFHBF
150
100
50
0
10
20
30
40
50
60
Cum Flt Hrs (x10^3)


MFHBF vs 6 Mo Period
Wuc 23B60
Figure F-2
MFHBF
250
200
150
100
50
0
Jul-Dec73
Jan-Jun74
Jul-Dec74
Jan-Jun75
Jul-Dec75
Jan-Jun76

Cum MMH/FH vs Cum Flt Hrs

WUC 23B60 TF30P412A

Figure F-3



Avg Repair Time vs

Cum Repair Actions

WUC 23B60

Figure F-4

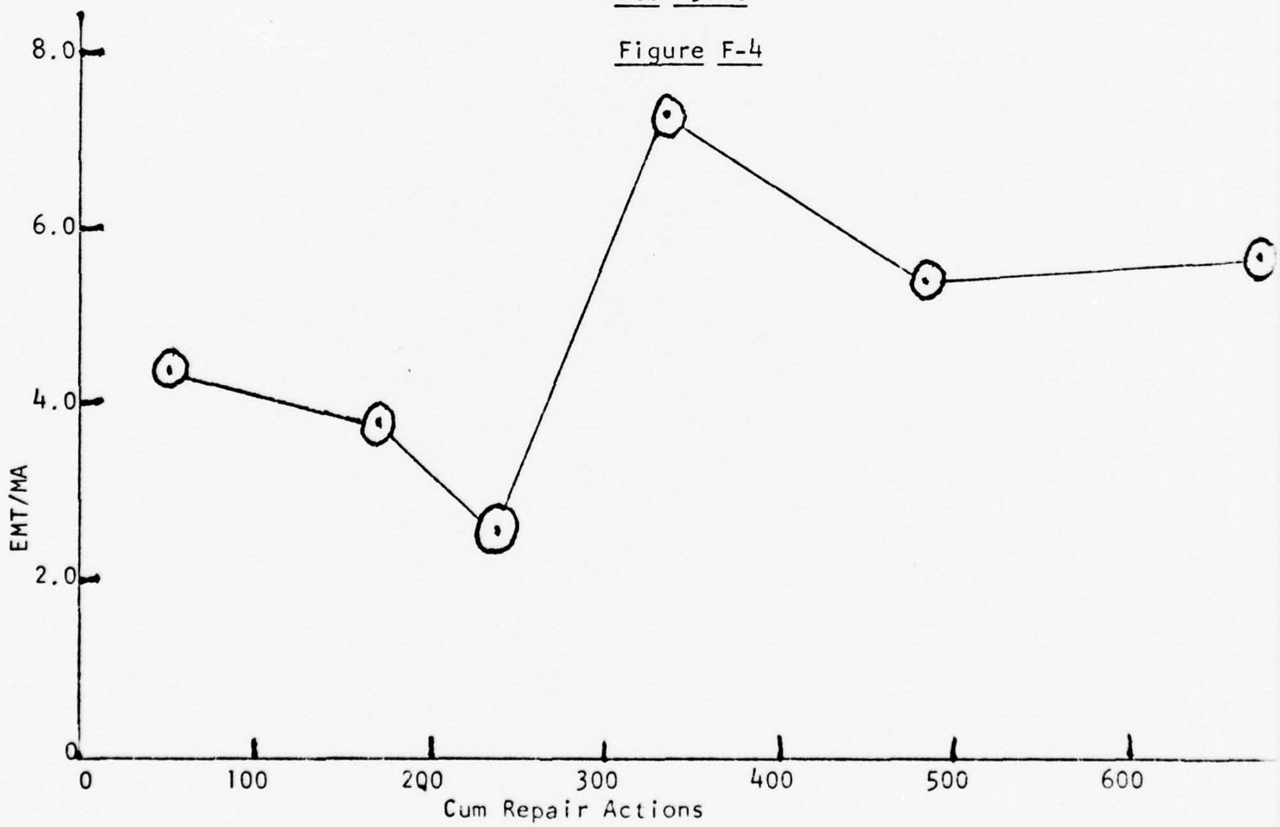


Table IV-8

WUC 23B60

Wuc 23B60 Main Fuel	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Tot Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	53	53	733	733	36	36	66.0	66.0	.31	.31	44.8	13.8	4.4
Jan-Jun 74	6,375	8,750	119	172	1,083	1,816	57	93	111.8	94.1	.17	.21	53.6	9.1	3.8
Jul-Dec 74	9,886	18,636	68	240	488	2,304	43	136	229.9	137.0	.05	.12	145.4	7.2	2.6
Jan-Jun 75	9,178	27,814	96	336	1,878	4,182	50	186	183.6	149.5	.21	.15	95.6	19.6	7.3
Jul-Dec 75	14,532	42,346	148	484	2,073	6,255	63	249	230.7	170.1	.14	.06	98.6	14.0	5.4
Jan-Jun 76	16,995	59,341	192	676	2,761	9,016	76	325	223.6	182.6	.16	.15	88.5	14.4	5.7

Work Unit Code (WUC) 23B70 Afterburner Fuel System

The cumulative reliability after peaking at 142 MFHBF at 18,000 flight hours, decreased slightly and appears to be leveling off at around 120 MFHBF (figure G-1). Figure G-2 shows that although the reliability in the past one and a half years is increasing, it is still far below the reliability (183 MFHBF) of the July - December 1974 period. The MMH/FH figure G-3 have steadily decreased to .166 over the three year data period. The average repair time (figure G-4) has also decreased significantly from 6.0 to approximately 3.5 hours EMT/MA. I believe that the MMH/FH will remain at its position and that the low reliability is due to a design problem due to the fact that reliability was highest when EMT was lowest. The data for the graphs in this section is contained in Table IV-9.

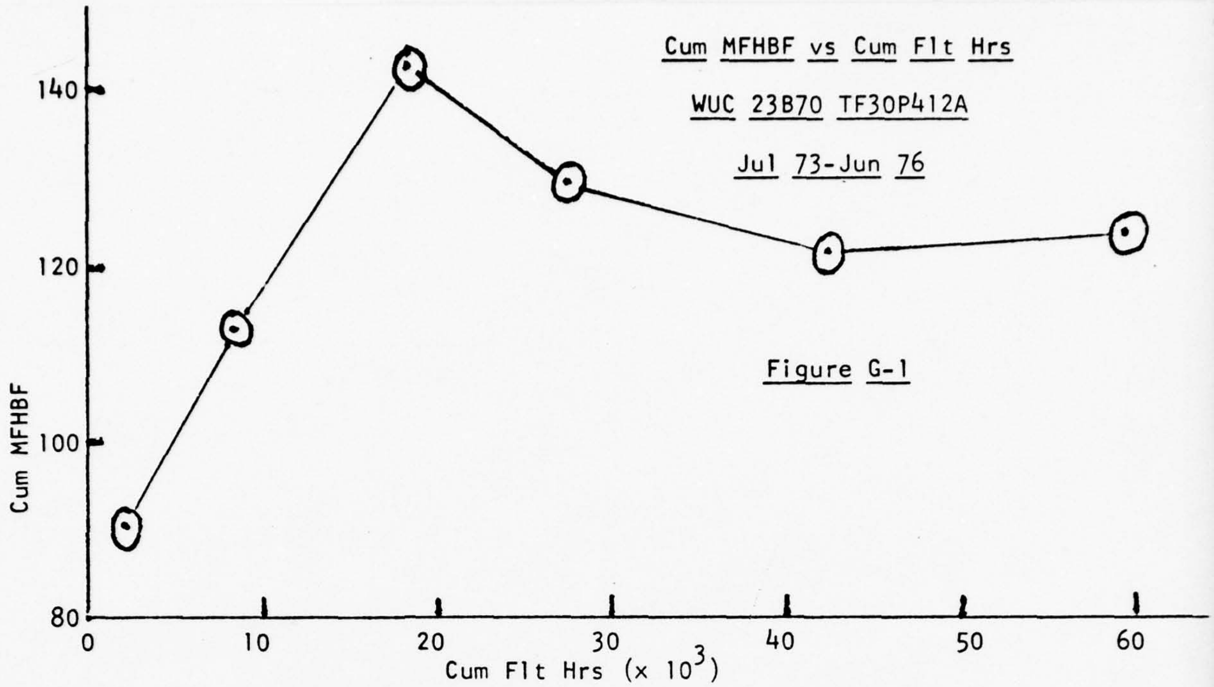


Figure G-1

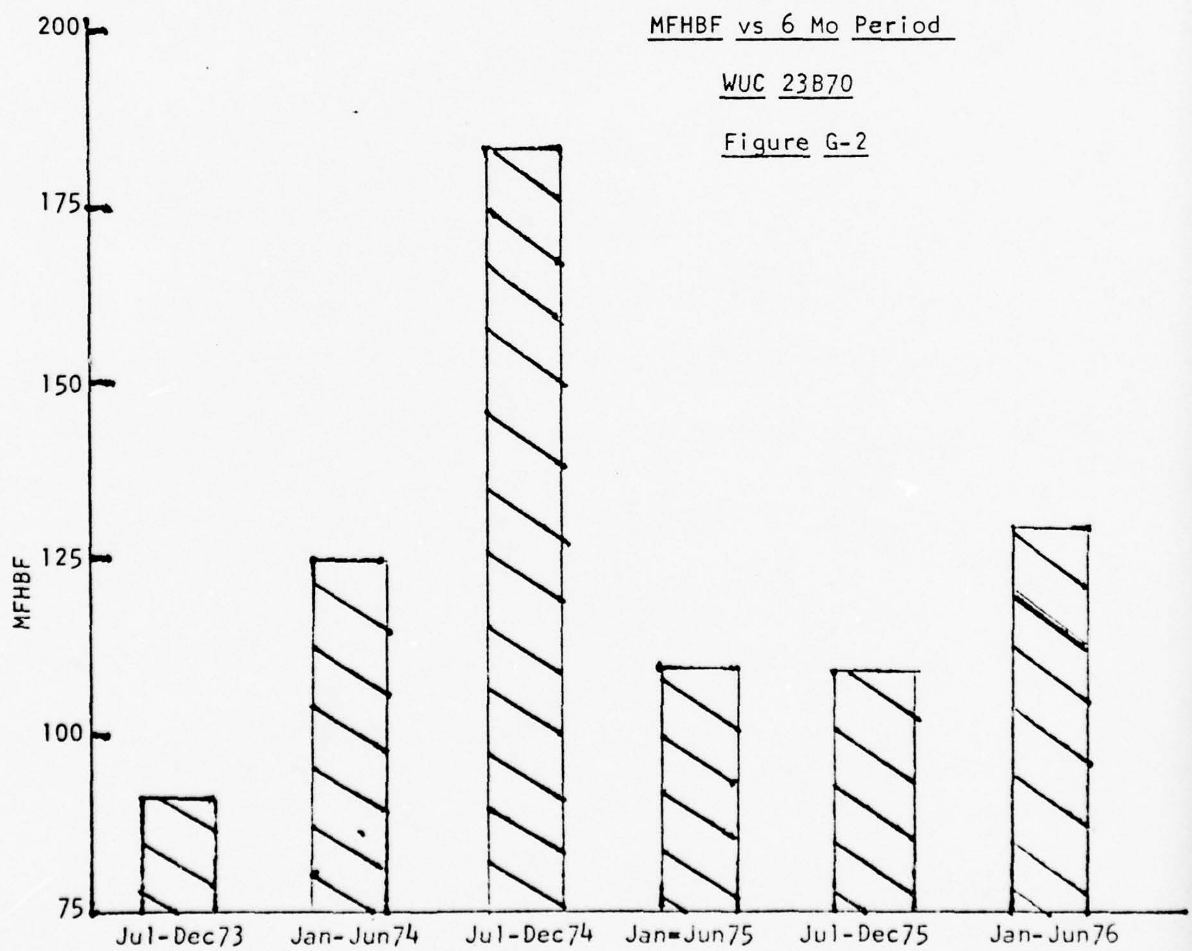
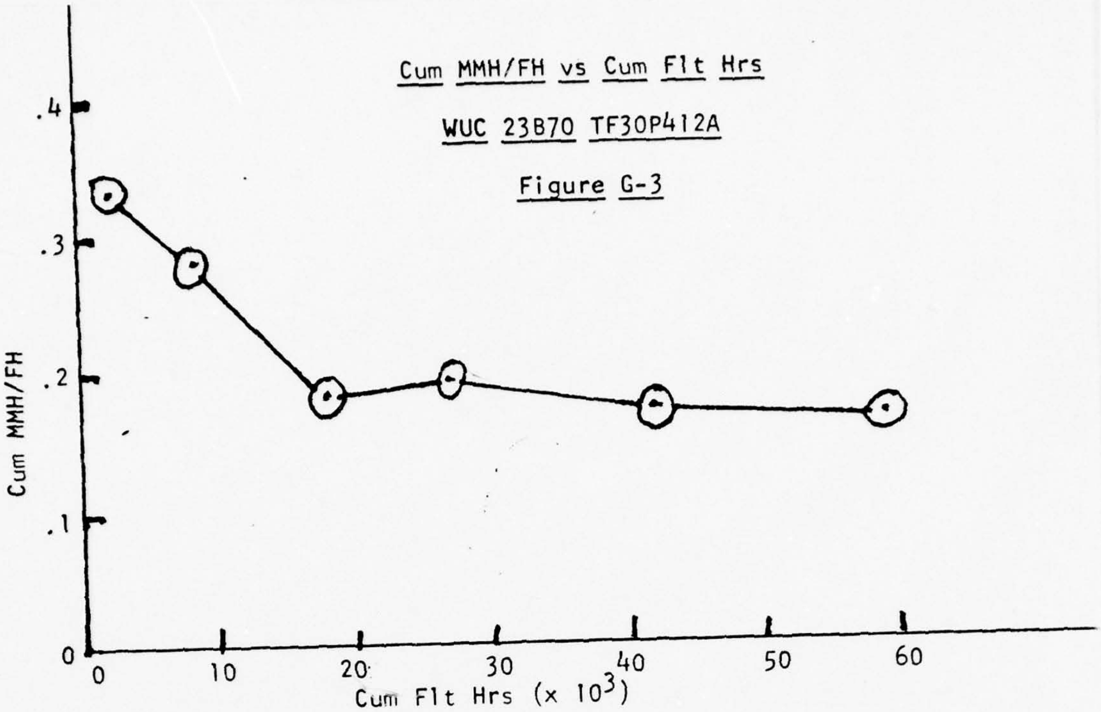


Figure G-2

Cum MMH/FH vs Cum Flt Hrs

WUC 23B70 TF30P412A

Figure G-3



Avg Repair Time vs

Cum Repair Actions

WUC 23B70

Figure G-4

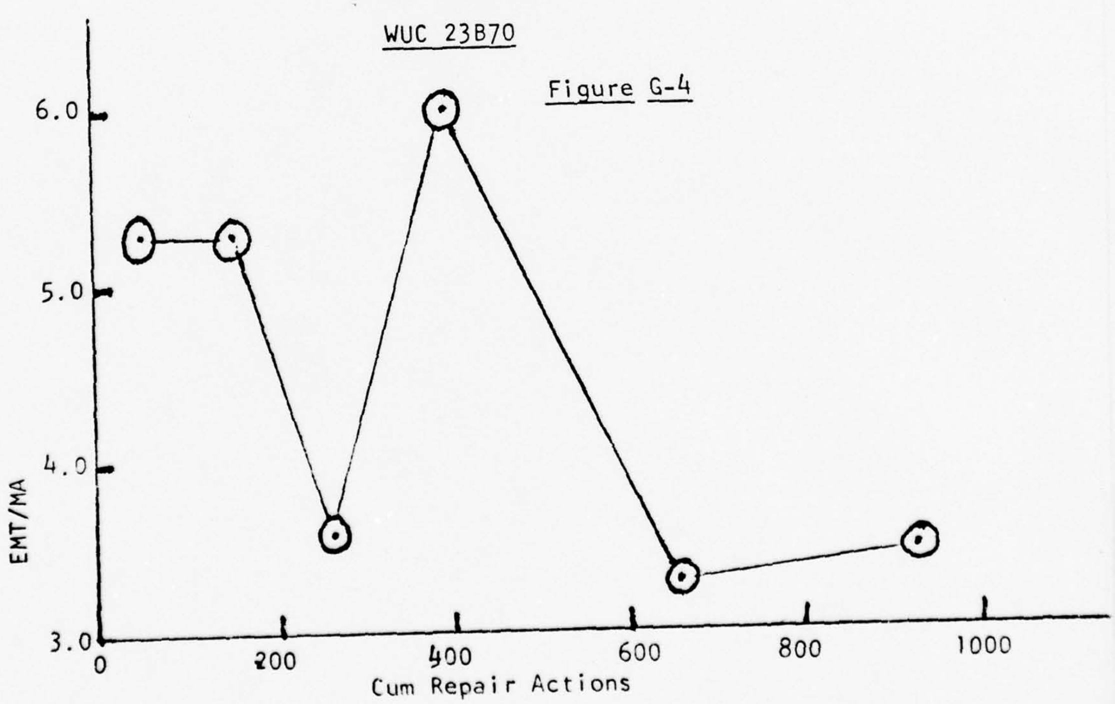


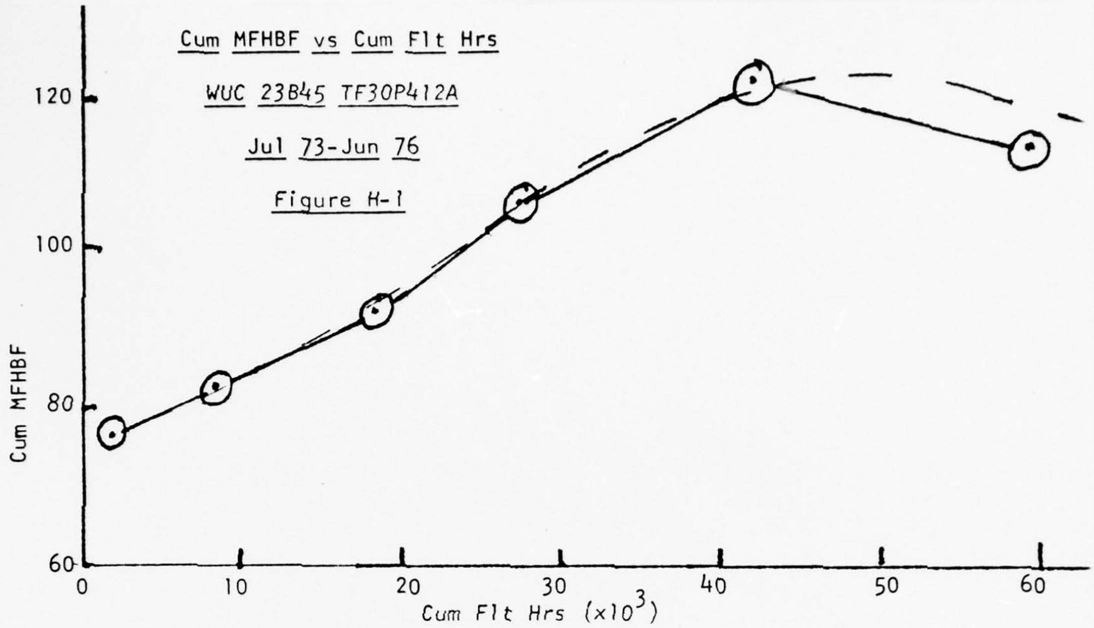
Table IV-9

WUC 23B70

WUC 23B70, A/B Fuel	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Tot Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	54	54	795	795	26	26	91.3	91.3	.34	.34	44.0	14.7	5.3
Jan-Jun 74	6,375	8,750	103	157	1,679	2,474	51	77	125.0	113.6	.26	.28	61.9	16.3	5.3
Jul-Dec 74	9,886	18,636	109	266	949	3,423	54	131	183.1	142.3	.10	.18	90.7	8.7	3.6
Jan-Jun 75	9,178	27,814	134	400	2,053	5,476	84	215	109.3	129.4	.22	.20	68.5	15.3	6.0
Jul-Dec 75	14,532	42,346	257	657	1,922	7,398	133	348	109.3	121.7	.13	.18	56.5	7.5	3.3
Jan-Jun 76	16,995	59,341	274	931	2,440	9,838	132	480	128.8	123.6	.14	.17	62.0	8.9	3.5

Work Unit Code (WUC) 23B45 A/B Duct and Nozzle

The cumulative reliability (figure H-1) appears to have reached a peak of about 120 MFHBF, and is leveling off between 100 and 120 MFHBF. The most recent six month period (January - June 1976) also dropped by over 50% of its value in the preceeding (July - December 1975) six month period (figure H-2). The MMH/FH (figure H-3) is averaging over the three year period a rate of .194. The EMT/MA has fluctuated within 2.0 hours of 5.5 hours/MA. There appears to be little experience gained and little value for an average repair time of 6.5 hours which has as associated cumulative MFHBF of 112.4, while an EMT/MA of 3.7 had a higher associated cumulative MFHBF of 120.6. There could be a maintenance problem, personnel training problem or a poorly designed component problem. I believe this problem to be a component design problem as the cumulative reliability and six month reliability both dropped in the period January - June 1976, and the MMH/FH and EMT/MA increased in the same period. The data for the graphs in this section are contained in Table IV-10.

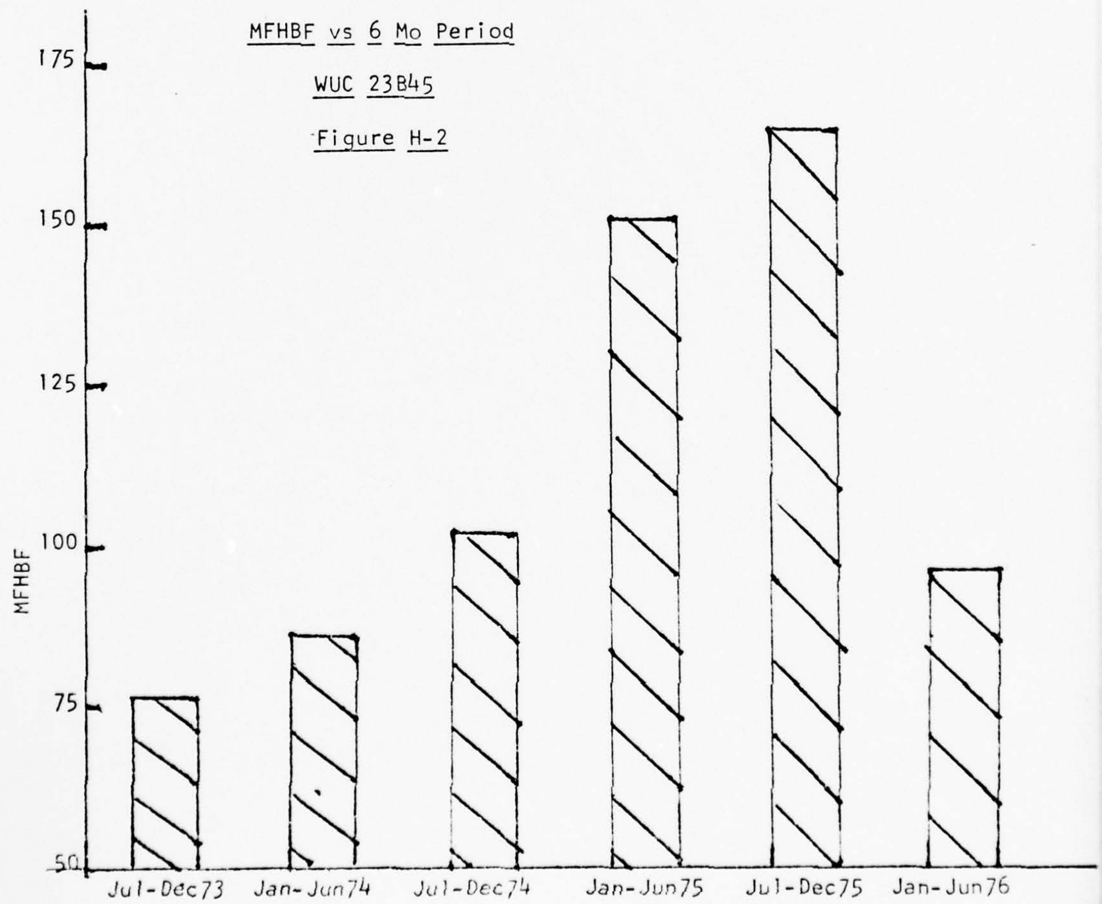


Cum MFHBF vs Cum Flt Hrs

WUC 23B45 TF30P412A

Jul 73-Jun 76

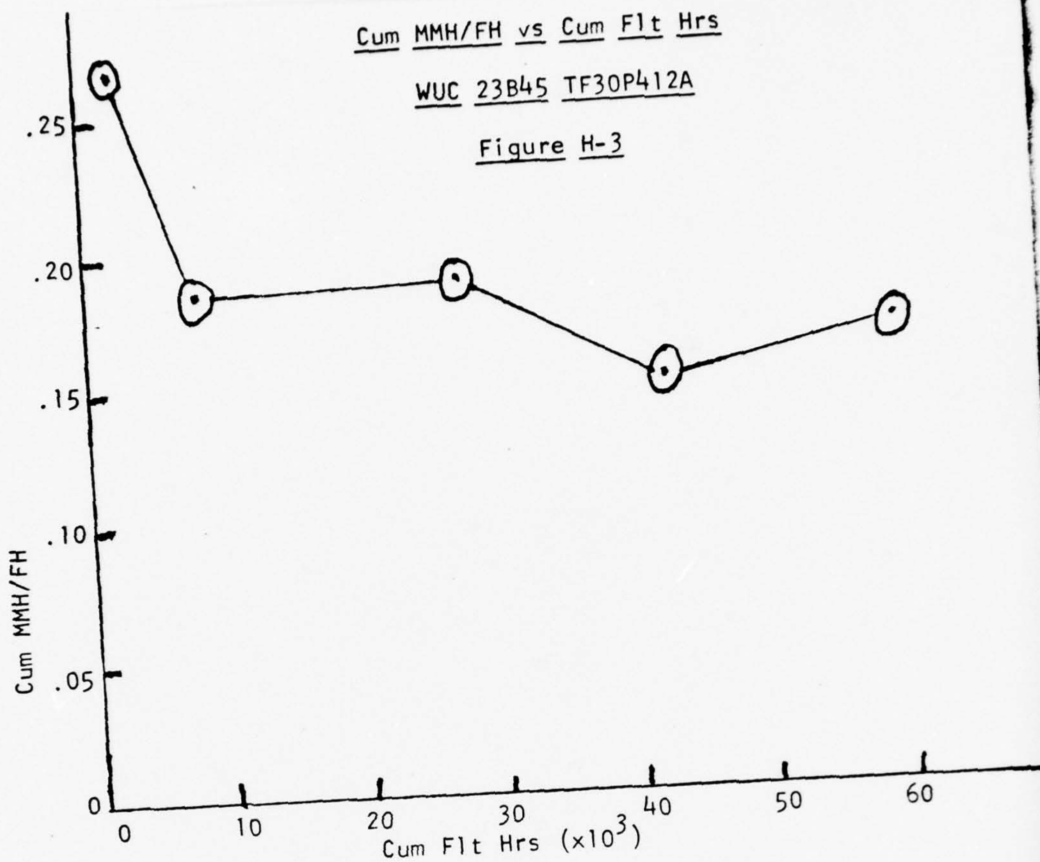
Figure H-1



MFHBF vs 6 Mo Period

WUC 23B45

Figure H-2


Cum MMH/FH vs Cum Flt Hrs
WUC 23B45 TF30P412A
Figure H-3
Cum MMH/FH
.25
.20
.15
.10
.05
0
0
10
20
30
40
50
60
Cum Flt Hrs ($\times 10^3$)

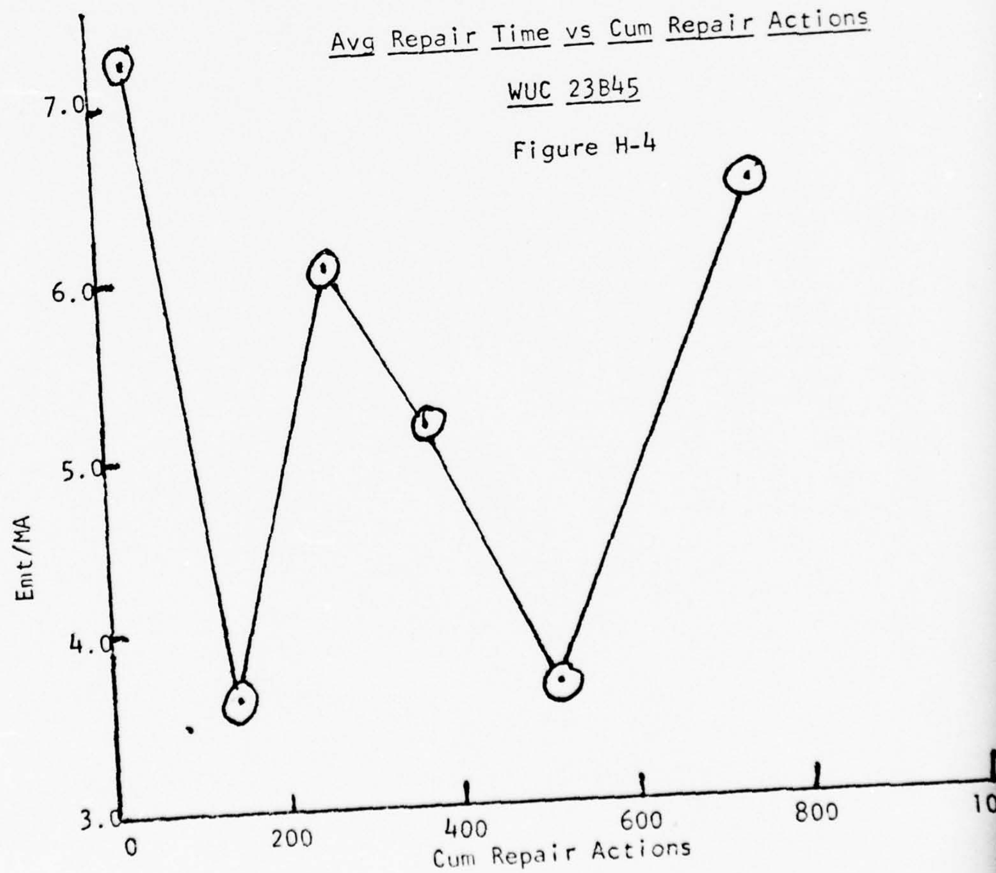

Avg Repair Time vs Cum Repair Actions
WUC 23B45
Figure H-4
Emt/MA
7.0
6.0
5.0
4.0
3.0
0
200
400
600
800
Cum Repair Actions

Table IV-10

WUC 23B45

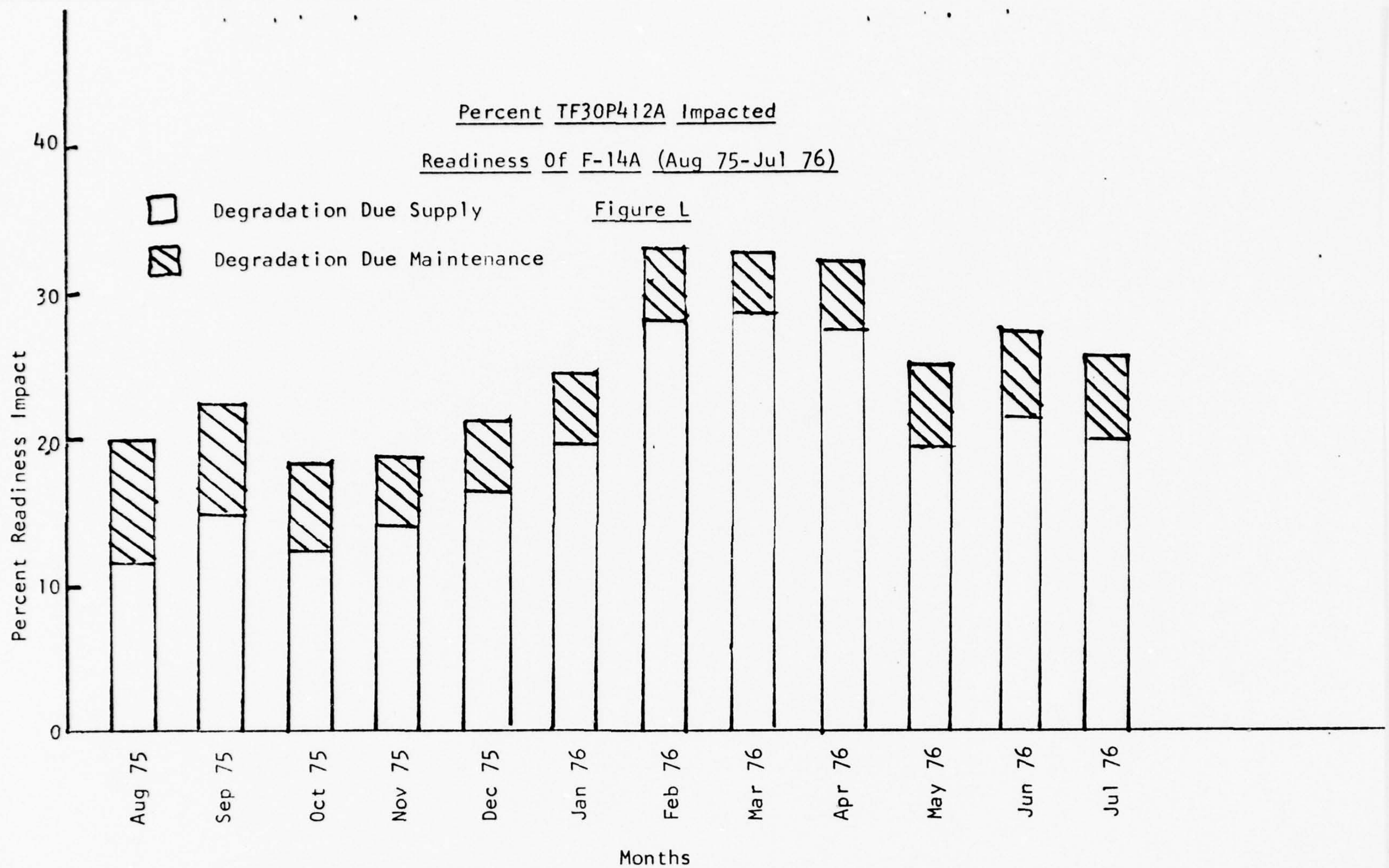
WUC 23B45 A/B Duct & Nozzle	Tot FH	Cum FH	Tot MA	Cum MA	MMH	Cum MMH	Tot Fail	Cum Fail	MFHBF	Cum MFHBF	MMH/FH	Cum MMH/FH	MFHBMA	MH/MA	EMT/MA
Jul-Dec 73	2,375	2,375	42	42	640	640	31	31	76.6	76.6	.27	.27	56.5	15.2	7.3
Jan-Jun 74	6,375	8,750	103	145	1,008	1,648	74	105	86.1	83.3	.16	.19	61.9	9.8	3.7
Jul-Dec 74	9,886	18,636	120	265	1,970	3,618	97	202	101.9	92.3	.20	.19	82.4	16.4	6.1
Jan-Jun 75	9,178	27,814	104	369	1,632	5,250	61	263	150.5	105.8	.18	.19	88.3	15.7	5.2
Jul-Dec 75	14,532	42,346	139	508	1,207	6,457	88	351	165.1	120.6	.08	.15	104.5	8.7	3.7
Jan-Jun 76	16,995	59,341	242	750	3,709	10,166	177	528	96.0	112.4	.22	.17	70.2	15.3	6.5

SECTION V

OPERATIONAL AVAILABILITY

Figure L is based on data contained in the Readiness Improvement Status Evaluation (RISE) reports, published by Naval Air Systems Command. A sample RISE is shown in Appendix III. The TF30P412A has been the number one ranking contributor to operational readiness degradation of the F-14A for the period August 1975 - July 1976. At first glance the chart in Figure L shows that in each month the largest contributor to Not Operationally Ready aircraft was due to supply. Consummables are a problem, but this should be greatly alleviated in January 1977 when fan blades will be readily available. Even so, is supply the real problem or actually the result of an initial poor effort in the Research and Development phase. All too often they blame the supply system for our lack of operational readiness, when in fact if we put more effort and money into Research and Development and emphasized ECP control in production, we would have a much smaller supply problem. An ECP that takes four to five years or longer to incorporate is a questionable change because of its impact on parts control, logistics, and cost. The Naval Air Systems Command Engine Logistics Branch has taken the initiative and requires a cost analysis (over the life cycle of the change) on every ECP submitted.

The Navy has a inherent supply problem due to the fact its aircraft operate from aircraft carriers at sea; so the last thing it needs is to proliferate the parts availability problem by flooding the system with ECP's.



Percent TF30P412A Impacted

Readiness Of F-14A (Aug 75-Jul 76)

Figure L

In a GAO report published in August 1976, it was reported that the operational readiness of the F-14A was 37.2 percent in calendar year 1975. (10:223)

The TF30P412A engine components have a relatively high Inherent Availability, as shown in Table V- 1. Inherent Availability is the probability that a system will operate effectively at any specific time in an ideally supported environment (all tools, spare parts, manpower available, etc.). It excludes scheduled maintenance time, logistics, and administrative down time.

The Exhaust Section and the Afterburner Duct and Nozzle Work Unit Codes have been the lowest elements of the engine in Inherent Availability (except for WUC 23B00, the removal and catch all WUC). The low Inherent Availability in these two sections should be expected from the previous Sections' analysis, which showed them to have a low reliability and a high number of MMH. It could be reasoned that if a section of the engine is low in availability, then the total engine will suffer the consequences. An aircraft engine is only as good (reliable, dependable,etc.) as its weakest link, and if one link is not functioning to its designed performance, it could lead to reduced engine performance, engine loss, aircraft loss, aircrew loss, etc. Inherent Availability should be used in the Test and Development Phase as a design-to specification.

The August 1976 GAO report also stated,

> Spare parts shortages were present at Miramar (Calif.) and Oceana (Va.) Naval Air Stations and on both cruises in which the F-14A's have taken part. Many F-14A's have been maintained in operating condition through the process of removing (cannibalizing) parts from other aircraft. (10:223)

INHERENT AVAILABILITY
TABLE V - 1

WUC	A_i	$\bar{M}_{ct}$ + MTBF	$\bar{M}_{ct}$	CUM MTBF
23B00	0.871	115.78	14.88	100.9
23B10	0.976	286.82	6.92	279.9
23B20	0.987	139.27	1.87	137.4
23B30	0.987	667.78	8.48	659.3
23B40	0.940	92.12	5.52	86.6
23B60	0.974	187.47	4.87	182.6
23B70	0.965	128.10	4.50	123.6
23B45	0.954	117.82	5.42	112.4

A lack of definition and emphasis on reliability in the past has caused the Navy to be faced with increasing Life Cycle Costs and less than desired operational readiness. Integrated Logistics Support (ILS) was supposed to buffer reliability, but has been relatively ineffective due to two factors:

1. The logistic pipeline has grown in length and size requiring a complicated and increased supply system to keep it functioning.

2. The high degree of unreliability of our equipment has overburdened the logistic procurement system. (18:13)

Vice Admiral Houser, Deputy Chief of Naval Operations for Air Warfare, described the spare parts situation with the F-14A this way:

> To go out and purchase great amounts of these (weapons replaceable assemblies and shop replaceable assemblies), while we didn't know how many or how frequently they were going to fail, or at what rate, would have been imprudent.
>
> So, we decided to take our lumps on lower readiness initially, but without ending up with an excessive amount of spare parts,

> particularly of the high value type. This has been true of the F-14... and it will be true in the future. We don't know as much about spares failure rates as we should, but we hope to buy the right quantities as the aircraft matures. (10:283)

Having relied on maintenance and supply pipelines for years, it might be difficult to reverse the trend and begin developing more reliable systems, but the pay offs in operation and support costs would more than compensate for the increased costs of more effort in the Research and Development Phase.

SECTION VI

CONCLUSION

From the TF30P6 engine to the present TF30P412A engine, there have been 451 power plant changes approved for incorporation. A proliferating spare parts problem, due to unreliable components of the TF30P412A has greatly affected the operational readiness and capability of the Navy's newest front line fighter aircraft. Mr. Willis J. Willoughby said:

> To repair some two million failures, the Navy is currently spending more than $.5 billion per year on spare parts alone--and this is a peacetime environment! Combat engagements would quickly sever this umbilical to the beach....Furthermore, readiness is not reliability. A capability to launch a mission doesn't guarantee its successful completion if it involves unreliable hardware; repairs stop when the mission begins. (18:13)

A mission cannot begin with the F-14A, if its engines are not functioning properly. Reliability and Maintainability play an important role in the determination of availability, logistics, spare parts and life cycle cost. Availability is also influenced by the logistics system, spare parts and life cycle cost. Once the desired inherent availability is decided upon, Reliability and Maintainability must be designed into the system to be able to meet that requirement. The Naval Material Command has established new guidelines within the scope of the current DOD and SECNAV policies to more clearly delineate a new methodology for implementing reliability programs in weapons system acquisition:

1. Set essential reliability requirements through the OR and DCP
2. Place Reliability criteria on a level with technical performance criteria
3. Demand reliàble design concepts
4. Minimize dependence on support
5. Ensure reliability by design not by chance (18:14)

SECTION VII

RECOMMENDATIONS

The following recommendations are based on the preceeding analysis:

1. The Navy should continue with its recent trend of placing greater emphasis on reliability by setting requirements early in the conceptual phase and placing it on a level with technical performance in importance.
2. It is recommended that increased scrutiny be given to approval of ECP's. A new design requires quantitative evidence that it is necessary and will improve the performance of the system. It also must be worth the cost of producing and be acceptable to the government. Fixed repair cost clauses (warranties) might be useful in incentivizing contractors to design in higher reliability.
3. The Navy could spend a total of about $1.7 billion to complete development and equip the entire F-14 fleet with a new engine like the F-401 (571). The new engine offers improvements important to the F-14A in its force projection mission, especially in air-to-air combat. (7:2) The GAO recommended that the Secretary of Defense evaluate the benefits to be derived from utilizing the new engine versus the cost of developing, producing and retrofitting it into the fleet. The Navy's primary concern should be to obtain a new engine with a high enough reliability to enable the operational availability to be improved instead of the importance of increased thrust.

4. The Air Force and the Navy are forming Aircraft Engine Program Offices which I believe is due to the fact that engine design has been lacking and most of our present aircraft engines were built on technology over ten years old. I think this is a positive step and should improve aircraft engine design reliability and will allow the proper Research and Development to be accomplished on this long-overdue area of system development. Consideration should be given by Secretary of Defense to establishing the Navy and Air Force Program Offices into a Joint Engine Program Office. By obtaining more commonality of engine, spare parts, over-haul facilities, training, etc., it would increase the logistical support of both services and enhance operational availability.

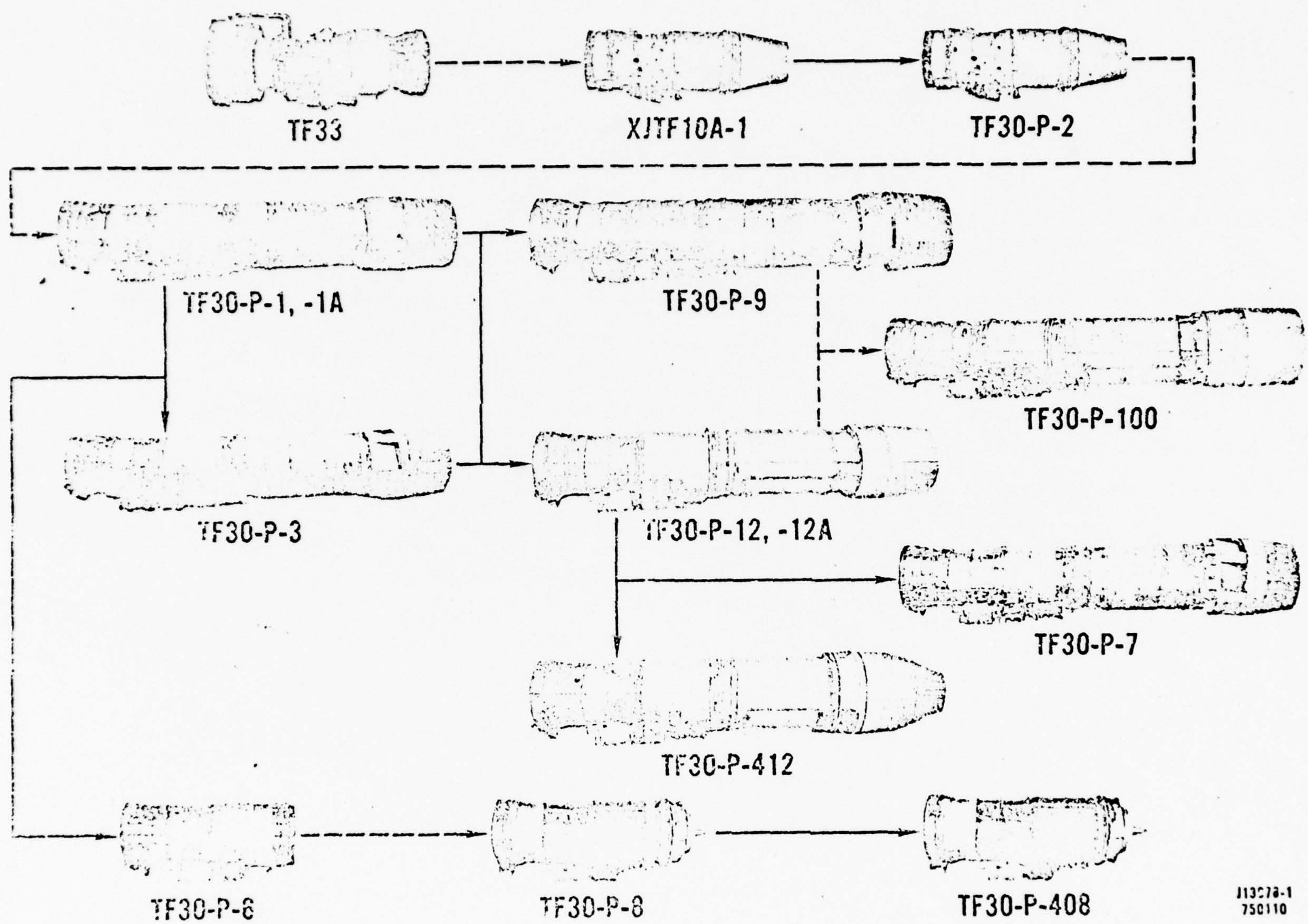
5. During the Model Qualification Test the engine should be put through as much of a mission test as possible. NAVAIRSYSCOM personnel have said that on new engines the Navy is requiring a 1,000 hour mission test (altitude testing, vibration measuring, throttle movement, etc.). This type of qualification should be incorporated in MIL-E-50007D (general aircraft engine specification for turbojets and turbofans) as it will place more emphasis on Research and Development and correcting problem areas prior to the production phase.

6. Further study should be undertaken to compare the TF30P412A turbofan engine to the other turbofan engines (i.e., TF30P408, TF34, etc.) This study should compare Reliability, Maintainability, Operational and Inherent Availability, and costs to achieve each level of operational availability.

APPENDIX I

TF30P412A Chronological History

TF30 ENGINE MODEL PROGRESSION



TF30P412 Chronology

April	1959	Design spec for commercial version of TF30 (JTF10) started
Dec	1959	First experimental JTF-10 run in test cell
Jan	1961	Initial run of TF30 engine
Oct	1962	Initial run of TF30 P-1
Dec	1964	First flight F-111A
Jun	1965	First production TF30 P-1 delivered for F-111A
Jul	1965	First Flight F-111A with TF30 P-1. Also first delivery Navy version of P-1 for F-111B
Mar	1967	Initial run TF30 P-12
May	1968	First production delivery TF30 P-12
Jun	1968	First flight TF30 P-12 in Navy F-111B
Aug	1970	Prototype TF30P412 engine delivered for F-14A
Dec	1970	First flight F-14A with TF30P412

APPENDIX II

PRE MQT DEVELOPMENTS, MILESTONES,

AND POST MQT PROBLEMS

Pre-MQT Development

Program Objectives

1. Adapt P-12 model to F-14A installation requirements
2. Improve P-12 performance to satisfy F-14A requirements
3. Maintain weight at 3,969 lbs.
4. Achieve engine and F-14A inlet compatibility.
5. Provide improved, reduced weight exhaust nozzle.
6. Improve turbine inlet temperature control.
7. Reduced smoke burner.
8. Provide maintenance and durability improvements for known problems of earlier models.

Pre-MQT Development

Program Milestones

	Milestone	Completion Date
1.	Program initiated	Jan 1969
2.	Initial distortion and turbulence test	May 1969
3.	First engine test	Nov 1969
4.	Inlet/engine compatibility test	Jul 1970
5.	PFRT	Aug 1970
6.	1st flight test prototype delivered	Aug 1970
7.	MQT	Mar 1971
8.	Penalty test on main burner	May 1971
9.	1st qualified engine delivered	Mar 1971
10.	Full Scale engine test hours thru MQT	2,530
11.	Development cost thru MQT	$21.7 Mil.

Significant Problems Since MQT

	PROBLEM	DATE	SOLUTION
1.	Engine/inlet incompatibility	1971	Inproved fan, A/B and A/B control system
2.	9th compressor airseal	1972	Incorporate stiffer seal
3.	Hung stall overtemperature	1973	None-proposed min. flow reset
4.	A/B mislights under "G" load	1974	Revised igniter sense line
5.	First stage fan blade durability	'74	Reduced stress by rework (PPC 438) Redesigned blade in process
6.	3rd stage fan rotor durability	1974	Tighten airseal fit (PPC 439) Back-up redesign in process
7.	Lack of fan blade containment	1974	Containment design T & E in process
8.	High turbine rivet failure	1975	Provide stronger rivet Back-up redesign in process
9.	Burner durability	1974	Improved cooling scheme under development
10.	High turbine vane durability	1974	Increased cooling scheme under development

Areas Requiring Special Effort

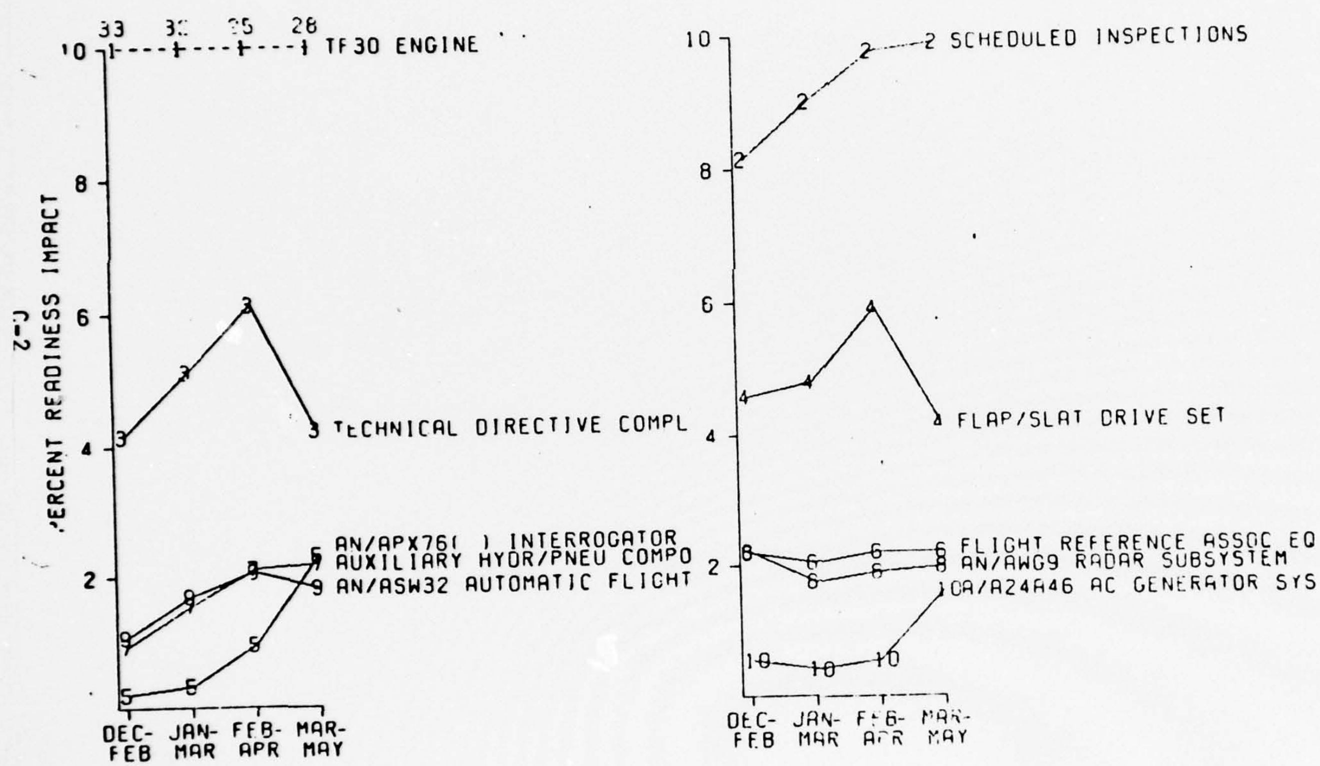
Prior To MQT (P-412)

1. Burner durability
2. Afterburner durability
   a. Liner
   b. Flameholder
3. Afterburner performance
   a. Augmentation
   b. Combustion instability
4. Exhaust Nozzle
   a. Flight load requirements
   b. Panel buckling
   c. Inter-panel seals
5. Engine/inlet compatibility

APPENDIX III

SAMPLE RISE REPORT

NAVAIRSYSCOM F-14A RISE 21 JUN 1976



C-2

RANK (A)	% READ. IMPACT (B)	SYSTEM (C)	NOR+RMC %M %S (D)	PROBLEM AND STATUS (E)	NEXT ACTION (F)	ASSIGNED (G)	DUE DATE (H)

The paragraphs below are keyed to the RISE column headings and describe the source and contents of the RISE Summary.

A. RANK - The first number indicates the ordinal position where the first work unit coded assembly falls based upon the total NOR (Not Operationally Ready) and RMC (Reduced Material Condition) hours for the three month period March 1976 through May 1976 The source of the ranking is MSOD Report 4790.A3364-01, Aircraft Degradation Ranking Summary, of 21 June 1976. The number in parentheses following the rank is last month's ranking.

B. % READ. IMPACT - The per cent this work unit code contributed to the total NOR+RMC hours for the three month period March 1976 through May 1976. (The total NOR+RMC hours reported against the work unit code assembly divided by the total NOR+RMC hours reported against the aircraft). The source of this figure is MSOD Report 4790.A3364-01, Aircraft Degradation Ranking Summary, of 21 June 1976.

C. SYSTEM (WUC) - The nomenclature for the work unit code assembly and the work unit code for that assembly in parentheses. Below this are listed statistics for the work unit code in this aircraft as reported in MSOD Report 4790.A2142-04, Reliability And Maintainability Trend Analysis Summary, of 21 May 1976 for the period October 1975 through March 1976. Statistics listed are: MFHBMA (Mean Flight Hours Between Maintenance Action), MFHBF (Mean Flight Hours Before Failure), MMH/FH (Unscheduled Maintenance Man Hours per Flight Hour), MMH/MA (Maintenance Man hours per Maintenance Action), and EMT/MA (Elapsed Maintenance Time per Maintenance Action). Listed below these statistics are annual maintenance costs attributable to the work unit code for this aircraft for Fiscal Year 1974. The costs are displayed for scheduled maintenance (SCHED), unscheduled maintenance (UNSCH) and total costs. The source of the cost information is the NAVAIRDEVCEN RECAP report for the aircraft.

D. NOR+RMC %M %S - This column displays the per cent of the %Read Impact (Column B) due to maintenance (%M) and due to supply (%S). The %M and %S figures are respectively the sum of the NORM (Not Operationally Ready Maintenance) and RMCM (Reduced Material Condition Maintenance) and the sum of the NORS (Not Operationally Ready Supply) and RMCS (Reduced Material Condition Supply) as reported for the work unit code in MSOD Report 4790.A3364-01, Aircraft Degradation Ranking Summary of 21 June 1976. Additionally, if all or part of this WUC assembly is managed under CLAMP (Closed Loop Aeronautical Management Program) the notation CLAMP Item Coml. (for commercial management) or CLAMP Item Organic (for organic management) will appear.

E. PROBLEM AND STATUS - A description of the most significant problems contributing to the unreadiness of the work unit code system, WRA or components and the status of actions underway to resolve these problems. This information is provided by the cognizant PMA (Project Manager, AIR), WSM (Weapon Systems Manager) or appropriate equipment manager during the RISE reviews conducted during the week of 12 July 1976.

F. NEXT ACTION - A concise statement of the next action required for each of the problems discussed in the previous column. Provided by the same source as the problem statement.

G. ASSIGNED - The activity, group, or function which has the responsibility to complete the action or to assure that the action is completed. Provided by the same source as the problem statement.

H. DUE DATE - The projected date when the action in the NEXT ACTION column is to be completed by the assigned action organization. Provided by the same source as the problem statement. When an action is not completed by the projected due date, that date is carried on the RISE with the next projected due date added.

RANK	% READ. IMPACT	SYSTEM	NOR+RMC %M	NOR+RMC %S	PROBLEM AND STATUS	NEXT ACTION	ASSIGNED	DUE DATE
1 (1)	27.58	TF-30 Engine (WUC 23B)	22	78	First stage fan blade problem and turbine section repair continue to cause excessive work load at all levels. Engine repair at NARF and IMA is impacted by shortages of RFI engine components, GSE and personnel. The engine cannibalization rate continued to drop throughout the fleet for the second consecutive reporting period. Manufacturer efforts on improved first stage fan blades are continuing with a planned production incorporation date of February 1977. A redesigned third fan disk is undergoing further evaluation.			
					PPC-445. 342 of 483 total Navy engines completed as of 7-12-76. NAVAIR issued IPPC-45 and Amendment 2 which require incorporation of more durable rivets in all engines having more than 250 hours since new. Estimated completion August 1976.	Monitor incorporation of IPPC-445	AIR-411	8-11-76
					PPC-438. 368 of 390 engines completed as of 7-12-76. Increase includes procurement of new engines with PPC-438 and expedited blades from manufacturer. Estimated completion October 1976.			
					PPB-59. Directed removal of 56 potentially over-stressed 3rd fan disks and blades sets and initiated a sampling plan to establish confidence for continued use in service. Thirteen disks and 17 engine blade sets completed inspection with no defects. Manufacturer will report to NAVAIR 7-76 on completion of initial testing phase.	Review report of sampling	AIR-53611	8-11-76
					PPB-60. Periodic eddy current inspection of all first stage fan blades is required every 45 hrs. All 438 and non 438 blades are affected.			
					PPB-61. One time inspection of chord dimension of all first fan blades is required. Inspection is also required after blending. NAVAIR 282132Z Apr 76 to TYCOMS provided additional information for PPB-61.			
					PPB-63. One time inspection of first fan blade attachment for score marks on engines reaching 600 hours since new and all engines processed through AIMDs and NARFs NORVA and NORIS.			
					Revised engine trim procedures have been issued by a RAC to the NA-01-14AAA-2-3-6 maintenance and trouble-shooting manual. Final operation and service instructions for the trim box will be published on 9-15-76 correcting all known discrepancies.	Issue revised maintenance and operating instructions manual NA-17-15AC-18	AIR-41731	9-15-75 11-1-75 3-1-76 4-30-76 9-15-76

APPENDIX IV

RAM ANALYSIS

TECHNICAL NARRATIVE COVER SHEET

TECHNICAL NARRATIVE COVER SHEET

A. REPORT TITLE. FLEET WEAPON SYSTEM RELIABILITY AND MAINTAINABILITY STATISTICAL SUMMARY TABULATION.

B. THIS REPORT PROVIDES THE RECIPIENT WITH A MEANS FOR COMPARATIVE ANALYSIS BY COMMAND, WORK UNIT CODE, AND AIRCRAFT OF THE RELIABILITY AND MAINTAINABILITY INDICES DEPICTED IN THE OUTPUT PRODUCT HEADER.

C. ALL DATA IN THE ATTACHED REPORT WERE OBTAINED FROM REPORTS SUBMITTED UNDER THE AVIATION 3-M SYSTEM. THE FORMS ANALYZED ARE

1. MAINTENANCE ACTION FORM -MAF-, OPNAV FORM 4790/40, CARD CODE 11.
2. MAINTENANCE ACTION FORM -MAF-, OPNAV FORM 4790/41, CARD CODES 21 AND 31.
3. 3-M FLIGHT DATA FORM, OPNAV FORM 3760/28, CARD CODE 76.

D. THE AIRCRAFT INCLUDED IN THIS REPORT ARE LIMITED TO THE FOLLOWING LIST UNTIL FURTHER NOTIFICATION BY NAVMAT 04142.

EA-3B	TA-4F	[illegible]	C-1A	[illegible]	F-4N		HH-2D		SP-2H		[illegible]
[illegible]	[illegible]	KA-6D	[illegible]	E-1B	[illegible]	AH-1J	SH-2F	UH-46D	[illegible]	S-2E	T-34B
TA-3B	A-4M	A-6E	C-9B	[illegible]	F-8J	UH-1K	HH-3A	[illegible]	P-3C	[illegible]	T-39D
A-4E	EA-6A	A-7C	EC-121M	RF-4B	F-14B	UH-1N	CH-3E	CH-53E	US-2B	T-2B	U-11A
A-4F	A-6B	[illegible]	KC-130F		UH-1E		SH-3G		US-2C	[illegible]	[illegible]

E. THIS REPORT PRESENTS AIRCRAFT RELIABILITY AND MAINTAINABILITY SUMMARIES BY WORK UNIT CODE, MAJOR COMMAND, AND NAVY-WIDE TOTAL. EACH AIRCRAFT SUMMARY CONTAINS A SEPARATE ENTRY FOR EACH MAJOR COMMAND POSSESSING THAT AIRCRAFT AND A NAVY TOTAL. THE MAJOR COMMANDS REPORTED ARE CNAL, FMFLANT, CNAP, FMFPAC, NASC, MARINE NON-FLEET, NATRA, AND NART.

F. THE REPORT INDICATES THE MEAN-FLIGHT-HOURS-BETWEEN-MAINTENANCE-ACTIONS #MFHBMA# AND MEAN-FLIGHT-HOURS-BETWEEN-FAILURE #MFHBF#. HOWEVER, THESE CALCULATIONS DO NOT CONSIDER MULTIPLE INSTALLATIONS WITHIN AIRCRAFT, TYPE OF MISSION, ITEM OPERATING TIME, VARIOUS EQUIPMENT CONFIGURATIONS FOR A GIVEN AIRCRAFT SERIES, AND MECHANICAL NON-TIME RELATED EQUIPMENT. THEREFORE, THE CALCULATED FIGURES SHOULD BE USED WITH DISCRETION AND ARE INTENDED TO BE USED AS A REFERENCE POINT THAT WILL SHOW TRENDS OVER A PERIOD OF TIME.

G. THE DATA IN THIS REPORT CAN BE CORRELATED WITH ADDITIONAL MEASUREMENT PARAMETERS #INVENTORY, SORTIES, ETC.# BY REFERRING TO THE PREVIOUS MONTHS UPDATED #P# LINE OR THE SIX MONTH SUMMARY #6# LINE FOR THE AIRCRAFT AND PERIOD CONCERNED AS CONTAINED IN THE MONTHLY 3-M AVIATION READINESS AND UTILIZATION SUMMARY, REPORT NUMBER MSD 4790.A2092-01. IN THE EVENT THAT EITHER INVENTORY, FLIGHT, OR MAINTENANCE DATA IS NOT RECEIVED FROM A GIVEN ACTIVITY PRIOR TO THE 4790,A2092-01 PRODUCTION DATE, ALL DATA FROM THAT ACTIVITY FOR THE SPECIFIED MONTH WILL BE DELETED FROM THIS REPORT. THOSE ACTIVITIES DELETED WILL BE LISTED IN THE MONTHLY 3-M AVIATION READINESS UTILIZATION UNTIMELY/DISCREPANCY DATA LIST, REPORT NUMBER MSD 4790,A2092-02. MSD HAS ALSO EXCLUDED FROM THIS REPORT ALL WORK CODE ENTRIES FOR WHICH 12 OR LESS THAN 12 MAINTENANCE ACTIONS HAVE BEEN REPORTED DURING THE CURRENT PROCESSING PERIOD.

H. EXPLANATION OF COLUMN HEADINGS.

1. WUC #WORK UNIT CODE#. THE FIRST FIVE DIGITS OF THE WUC, EXCEPT A ZERO IS PLACED IN THE 5TH DIGIT IF THE ACTION TAKEN IS 9.

2. NOMENCLATURE. THE NOMENCLATURE FOR THE WORK UNIT CODE CONTAINED IN COLUMN 1.

3. COMMAND. THE MAJOR COMMAND OR NAVY-WIDE TOTAL.

4. TOTAL FLIGHT HOURS. THE NUMBER OF FLIGHT HOURS REPORTED IN CARD CODE 76 TRANSACTIONS.

5. TOTAL MAINTENANCE ACTIONS. THE NUMBER OF UNSCHEDULED MAINTENANCE ACTIONS INITIATED AS REPORTED IN CARD CODES 11, 21, AND 31. EACH CHANGE IN THE JOB CONTROL NUMBER, LESS SUFFIX, WITHIN A GIVEN COMPONENT LEVEL WORK UNIT CODE #FIRST FIVE DIGITS# CONSTITUTES ONE MAINTENANCE ACTION.

6. MFHBMA #MEAN-FLIGHT-HOURS-BETWEEN-MAINTENANCE-ACTION#. THE TOTAL FLIGHT HOURS DIVIDED BY THE NUMBER OF MAINTENANCE ACTIONS INITIATED.

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7. MLI REPAIR FAILURES. THE NUMBER OF MAINTENANCE ACTIONS CONTAINED IN PARAGRAPH H-8 BELOW THAT INDICATED THE NECESSARY REPAIRS WERE ACCOMPLISHED BY ORGANIZATIONAL LEVEL MAINTENANCE EFFORT, E. G., THE CARD CODE 11 OR 31 REPORTING A FAILURE ACTION TAKEN CODE ALSO CONTAINED A MAINTENANCE LEVEL 1.

8. TOTAL FAILURES. THE NUMBER OF MAINTENANCE ACTIONS THAT WERE CONFIRMED AS FAILURES BY THE ACTION TAKEN CODE REPORTED IN CARD CODES 11 AND 31 TRANSACTIONS. EACH CHANGE IN THE JOB CONTROL NUMBER, LESS SUFFIX, WITHIN A GIVEN COMPONENT LEVEL WORK UNIT CODE #FIRST FIVE DIGITS# CONSTITUTES ONE FAILURE PROVIDING THE RECORD OR ANY RECORD OF A GROUP CONTAINING THE SAME JOB CONTROL NUMBER, WORK UNIT CODE, AND TYPE EQUIPMENT HAS AN ACTION TAKEN CODE OF 1 THROUGH 9, B, C, OR Z AND A MALFUNCTION DESCRIPTION CODE OF OTHER THAN A CONDITIONAL MALFUNCTION. ADDITIONALLY, CORROSION CONTROL ACTIONS ACCOMPLISHED AT ORGANIZATIONAL LEVELS ARE NOT CONSIDERED FAILURES, E.G. ACTION TAKEN CODE Z RECORDS REFLECTING MAINTENANCE LEVEL 1 EFFORT. THE CONDITIONAL MALFUNCTION CODES ARE 000, 085, 093, 105, 108, 142, 158, 246, 301, 303, 311, 447, 602, 651, 730, 731, 758, 787, 788, 799, 800, 801, 803, 804, 825, 836, 878 AND 931.

9. MFHBF #MEAN-FLIGHT-HOURS-BETWEEN-FAILURES#. THE TOTAL FLIGHT HOURS DIVIDED BY THE TOTAL NUMBER OF FAILURES.

10. TOTAL MAINTENANCE MAN-HOURS. THE NUMBER OF MAN-HOURS EXPENDED IN THE PERFORMANCE OF UNSCHEDULED MAINTENANCE AS REPORTED IN CARD CODES 11, 21, AND 31.

11. MAINT M/H PER F/H #MAINTENANCE MAN-HOURS PER FLIGHT HOUR#. THE TOTAL MAINTENANCE MAN-HOURS DIVIDED BY THE TOTAL FLIGHT HOURS.

12. M/H PER MAINT ACT #MAINTENANCE MAN-HOURS PER MAINTENONCE ACTION#. THE TOTAL MAINTENANCE MAN-HOURS DIVIDED BY THE NUMBER OF MAINTENANCE ACTIONS INITIATED.

13. EMT PER MAINT ACT #ELAPSED MAINTENANCE TIME PER MAINTENANCE ACTION#. THE TOTAL ELAPSED MAINTENANCE TIME AS REPORTED IN CARD CODES 11, 21 AND 31 DIVIDED BY THE NUMBER OF MAINTENANCE ACTIONS INITIATED.

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WUC	NOMENCLATURE	COMMAND	TOTAL FLIGHT HOURS	TOTAL MAINT ACTIONS	MFHBMA	ML1 REPAIR FAILURE	TOTAL FAILURE	MFHBF	UNSCH MAINT MAN HOURS	MAINT M/H PER F/H	M/H PER MAINT ACT	EMT PER MAINT ACT
73781	TD965/AQA7%V0 DEMULTIPLEXER	CNAL	11,790	[illegible]	37,2	15	137	86.1	[illegible]	.178	4.0	2.6
		CNAP	5,464	[illegible]	70,1	2	21	260.2	255	.047	3.3	2.7
		TOTAL	17,649	[illegible]	43,5	17	160	110.3	[illegible]	.087	3.8	2.6
73782	MX8439/AQA7%V0 FREQ MULTIPLIER STOR	CNAL	11,790	315	37,4	7	134	88,0	1,143	.097	3.6	2.5
		CNAP	5,464	139	39,3	3	49	111.5	395	.072	2.8	2.3
		NASC	395	21	18,8	0	5	79.0	43	.108	2.0	1.5
		TOTAL	17,649	475	37,2	10	188	93.9	1,580	.090	3.3	2.4
TOTAL	***73000*** BOMBING NAVIGATION	CNAL	11,790	6,723	1,8	1,230	3,307	3.6	23,04[illegible]	1.954	3.4	2.5
		CNAP	5,464	2,017	2,7	419	862	6.3	6,45[illegible]	1.182	3.2	2.3
		NASC	395	225	1,8	16	64	6.2	632	1.601	2.8	2.1
		TOTAL	17,649	8,965	2,0	1,665	4,233	4.2	30,13[illegible]	1.707	3.4	2.4

DATA IS SEQUENCED BY WORK UNIT CODE, IDENTIFIED BY NOMENCLATURE, AND SUMMARIZED BY MAJOR COMMAND AND NAVY-WIDE TOTALS. WUCS ARE SUMMARIZED AT THE SYSTEM (2ND), AND ASSEMBLY/SET (4TH) LEVELS

TOTAL COMMAND P-3C FLIGHT HOURS FOR THE REPORTING PERIOD

NUMBER OF UNSCHEDULED MAINT. ACTIONS INITIATED BY CARD CODES 11, 21, AND 31. EACH CHANGE IN JOB CONTROL NUMBER, LESS SUFFIX, WITHIN A GIVEN COMPONENT LEVEL WUC CONSTITUTES ONE MAINT. ACTION

MEAN FLIGHT HOURS BETWEEN MAINT. ACTIONS IS THE TOTAL FLIGHT HOURS DIVIDED BY THE NUMBER OF MAINT. ACTIONS INITIATED

NUMBER OF FAILURES REPAIRED AT THE ORGANIZATION LEVEL. ACTION CONFIRMED BY CARD CODES 11 OR 31 WHICH INDICATE ACTION TAKEN AT THE ORGANIZATIONAL LEVEL.

MEAN FLIGHT HOURS BETWEEN FAILURES IS THE TOTAL FLIGHT HOURS DIVIDED BY THE NUMBER OF FAILURES

NUMBER OF MAINT. ACTIONS CONFIRMED AS FAILURES BY THE ACTION TAKEN CODE (1 THRU 9, B, C OR Z) AND A MALFUNCTION CODE OTHER THAN A CONDITIONAL MALFUNCTION.

NUMBER OF UNSCHEDULED MAINTENANCE MANHOURS REPORTED IN CARD CODES 11, 21 AND 31

MAINT. MANHOURS PER FLIGHT HOUR IS THE TOTAL MAINT. MANHOURS DIVIDED BY THE TOTAL FLIGHT HOURS

MAINT MANHOURS PER MAINT ACTION IS THE TOTAL MAINT MANHOURS DIVIDED BY THE NUMBER OF MAINT ACTIONS INITIATED.

ELAPSED MAINT. TIME PER MAINT. ACTION IS THE TOTAL ELAPSED MAINT. TIME REPORTED ON CARD CODES 11, 21 & 31 DIVIDED BY THE NUMBER OF MAINT. ACTIONS INITATED.

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